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Sustaining the Gwent Levels

Underdrainage and Farming: Current State – Future Management

For

RSPB Cymru

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1 Executive summary

The importance of the Gwent Levels for wildlife has long been recognised and is reflected in the area's statutory designations: eight SSSIs covering 5,856ha; and the area lies alongside the Severn Estuary which is a designated SPA, SAC and Ramsar site as well as an SSSI.

The drainage system in the Gwent Levels comprises a diverse, highly interdependent network of watercourses, surface morphologies and underground conduits. These function in an agricultural landscape underpinned by challenging soils that can limit farming practices.

Improving these systems could significantly enhance the productivity of the area's farms. However, due to the complexity of hydraulic interactions within the network, it is not advisable that improvements are carried out in isolation or without careful consideration of their consequences. Furthermore, there is the potential to damage the established biodiversity, brought about through intensification of farming practices made achievable through soil improvements.

The Internal Drainage District, part of Natural Resources Wales now manages the reens in the same way as the Internal Drainage Board did. There is an IDD Advisory Group made up of farmers and stakeholders who can advise the IDD, and NRW work with farmers at various levels including management agreements for SSSIs. As the drainage system is a connected system it is beneficial to look at the system as a whole rather than individual farm holdings.

It is essential that a holistic approach is adopted that involves and encourages farmers to understand, engage with riparian management and take responsibility for the balance between farm improvements and the protection of the area's unique environment.

Across the UK, underground drainage of agricultural land has been supported by government aid schemes designed to ensure food security and has been shown to increase the flexibility of land use and improve yields. Drainage systems installed before the 1980s are now reaching the end of their design lives and without replacement (if the land remains in arable cropping) could cause yields to fall and render soil more vulnerable to damage.

Ongoing changes in government policy in Wales are shifting the emphasis of aid away from production to delivery of environmental benefits and accrual of natural capital, sustainable intensification has a role to play in agriculture, where yields can be enhanced without causing environmental harm. Agricultural land drainage may have a role to play in this area where it can be installed without risk to the environment and changes in cropping may remove crops like maize from many rotations.

On the Gwent Levels, proposals for new or replacement piped drainage installations are likely to become rare due to the cost of comprehensive land drainage systems and relationships between land and water levels in the area. With the exception of high value crops, the extended payback period of investments in drainage systems are unattractive.

The development of markets for carbon sequestration and ecosystem services is likely to stimulate interest in diversified farming systems nationally. With anticipated changes in national economic and environmental policies it is likely that farmers and land managers will be open to diversification and adaption of practices, particularly in the Gwent Levels where many farming businesses have relied on payments from government.

The direction of farming systems in the Levels will have to take account of and enhance the traditional drainage network in order to protect the biodiversity it supports and conserve historical landscape features to improve the area's resilience and sustain it for the benefit of future generations.

It is anticipated that improved understanding of the system and recognition of limits will encourage the implementation of sustainable, nature-friendly farming and diversification into low intensity agriculture and the growing of crops better suited to the local environment.

2 Introduction

This report is part of the Sustaining the Gwent Levels, Sustainable Management Scheme and has been commissioned by the RSPB Cymru with support from Welsh Government Rural Communities Fund's Rural Development Programme 2014-2020, funded by the Welsh Government and the European Union. The report sets out the relationships between agriculture and water management in the Gwent Levels and the likely impact of changes in water management on farm businesses and the local environment.

The report has been researched and written by Reading Agricultural Consultants Ltd (RAC). A wide range of stakeholders, colleagues and other independent specialists have been consulted in the course of its preparation and individuals and their contributions have been critical to enhancing RAC's understanding of the area, its hydrology ecology and their relationships with farming.

The principal issues and impacts considered by the report comprise:

- changes to the length of the farming season made possible by underdrainage;
- how the installation of underdrainage might drive changes in husbandry;
- how fertiliser and/or pesticide use might change with consequent changes in husbandry;
- interactions between the cultural and biodiversity value of the area, and social and economic aspects of agriculture and flood defence;
- how productivity and profitability might change for different husbandry types; and
- an assessment of impacts of reduced surface water levels on farming.

This report is part of a series of reports produced as part of the Welsh Government's Sustaining the Gwent Levels SMS project and draws heavily on the findings of a recent ecohydrological study of the Gwent Levels carried out by Rigare and a separate RAC report on the costs of wetland landscape restoration and maintenance in the area. The Rigare report sets out the wider geological, topographical, historical, ecological and functional hydrological background to the area. When considering agriculture in any setting, it is important to understand the physical and cultural history of an area as well as its soil, hydrology and climate in the context of farming and relevant background information may be duplicated in this report.

The elements of the principal issues and impacts are addressed in the three main sections of this report, covering:

A. Drivers for change and its consequences;

B. Farming benefits and the impact of water level change;

C. Developing a vision for future drainage and land management in the Gwent Levels.

The conclusions drawn are supported by referenced appendices that include a financial analysis and descriptions of drainage types and future recommendations.

The area of study in the project specification is shown below:

Fig. 1: The extent of the Gwent Levels

Wet habitats are important for birds and other wildlife and drainage can degrade important wildlife habitats. There are eight SSSIs on the Gwent Levels covering 5,856ha within which there is a requirement to consult with NRW for any operation which is likely to damage the Scientific Interest.

Outside of the SSSIs there is no requirement for the environmental assessment of new agricultural land drainage schemes where the land is improved, although there is a requirement for any farming operation undertaken on semi-natural land that significantly changes the way land is farmed or alters the species mix in the long term. Any land falling within the definition of semi-natural, must have a Screening Application made prior to any works commencing, (Environmental Impact Assessment (Agriculture) (Wales) Regulations[1]). The regulations do not apply to works on surface drainage.

3 Background

The Gwent Levels comprise more than 6,000ha of land that lies between Cardiff, Newport and Chepstow and the Bristol Channel. The land closest to the sea is the highest part of the Levels resulting in a topography going northwards that generally falls by up to four metres from the coast, that is, much of the inland area is lower lying than the land at the coast.

There are around 250 active farms in the area[1], however, the silty clay soils of the area and relatively high levels of rainfall create unfavourable conditions for many agricultural field operations. As a result of the topography, the predominantly Grade 4 soil classification (best UK grades soil quality Grade 1 and poorest Grade 5) and the wetness of the area, most agricultural enterprises in the Levels are based on grass-fed livestock systems, as opposed to arable cropping.

Most fields traditionally had a ridge and furrow landform, which encouraged run off and accumulation of surface water leaving dry areas that allowed longer but limited grazing in the spring and autumn and provided wetland habitat for long periods**.** Typically, surface drainage in the Levels is dendritic in form, a network of trunks, branches and twigs. Large, generally north-south running drains, take water out to sea. These main rivers are fed by a network of reens (drainage channels) which take water from the field systems and discharge it into the Bristol Channel. This network is essential for the successful farming of the area but it also supports unique aquatic habitats, the majority of which are designated Sites of Special Scientific Interest[2].

Therefore, while this is a highly evolved established drainage system that in principle should function effectively, the complex relationships within the surface ditch system mean that changes to the drainage of individual fields or individual ditches can have far reaching consequences for relatively large parts of the complex interconnected whole of the Levels' drainage network and environment dependent habitats. It is critical that a holistic approach to drainage is adopted to support farm and other rural developments as well as enhancing and protecting the Levels' valuable ecological habitats.

[1] https://gov.wales/agricultural-small-area-statistics-2002-2020
[2] http://lle.gov.wales/map#m=-2.93214,51.54339,12.277777791023254&b=europa&l=1356;

A Drivers for change and its consequences

Since WW1, the elevated coastal strip of the Gwent Levels has seen the development of arable farming with the low-lying inland areas used for grazing land. This principally remains the same today although the trends of and drivers for change vary through the range of farming systems. However, the development of drainage in the lower lying area would see less land remaining as low grade pasture and more arable and intensive forage production, which, without high standards of husbandry, brings with it increased risk of harm to the aquatic environment.

The dendritic drainage system of trunks, branches and twigs reflects historical responsibilities and land ownership and the dimensions of each watercourse reflect the area of land it drains as shown in Figure 2 below:

Fig.2: Google Earth image showing layout of historical land drainage

Individual farms are reliant on their own capacity to drain individual fields, they are also reliant on others for ensuring that water is effectively drained further away *via* the network of reens. Failure to ensure the effectiveness of the overall system would create flooding or the misfunctioning of the drains higher up the system. In summary, the number of individual farms and their reliance on the functioning drainage network as a whole, makes it critical to ensure a coordinated approach is adopted.

The agricultural sector's/farmers' default business position conventionally focuses on increasing productivity to remain competitive. Improving a farms drainage can help achieve this by balancing the supply of nutrients and water to suit crop demand, as well as maintaining a soil structure capable of supporting machinery or livestock moving across its surface without suffering damage.

Conventionally, the cumulative farming benefits of improved yields, and greater productivity, set amongst a competitive agricultural market industry will tend to drive individual farmers to seek new and improved farming practices. However, many of the practices considered would align with late 20th Century farming which relies heavily on high output systems driven by high inputs using the land as a growing medium, rather than a better aligned agroecosystem approach that recognises the natural resource constraints of soil, water and biodiversity within which it operates.

A sustainable approach to farming in the Levels would have a positive impact on natural, social and human capital but may not be immediately attractive to farming stakeholders. This can be overcome by the adoption of an approach based on the principles of sustainable intensification, which sustains or increases farming returns whilst avoiding adverse environmental impacts and improving the environmental value of land.

The network of reens in the Gwent Levels is now managed as an Internal Drainage District (IDD) by Natural Resources Wales (NRW), this includes an IDD Advisory Group made up of farmers and stakeholders who can advise the IDD. NRW replaced an Internal Drainage Board (IDB) as manager of the IDD in 2015. This remains a contentious issue with some farming stakeholders interviewed in the course of this research.

Farming generally is in a period of uncertainty related to the imminent replacement of farm payments with a scheme based on the Sustainable Management of Natural Resources (SMNR) and volatile markets influenced by developing trade agreements and coronavirus. As described above, change in the late 20th Century was driven by production, aided by developments in plant breeding, machinery, and fertilisers and pesticides. Ongoing change will be most likely be driven by government payments and a continuing need for land-based businesses to develop and compete in changing physical and financial environments, guided by the principles of sustainable intensification.

Arable

Many arable farmers have existing land drainage systems, most financed through government initiatives in the post-WW2 period, that have been well maintained but are now nearing the end of their design lives. Therefore, these systems would require replacement over the next decade to prevent soil wetness limiting operations and the range of crops that can be grown and thus having an adverse impact on farm incomes.

Other arable systems may have a land drainage system which has been neglected and failed. Managers of this land are likely to suffer poor yields relative to drained land and face pressure to restore drainage systems that are most likely beyond the end of their design life.

Finally, the managers of some land currently in grass production and marginal for arable production may consider drainage in order to implement a more profitable arable rotation that may include energy crops.

The environmental consequences of maintaining or developing arable farming and associated drainage systems are related to land management and its impact on soil structure and water quality. The findings of the Rigare report suggest that it is unlikely that the surface water regime will be adversely impacted by the installation of drainage but concerns centre around the risks associated with nutrient loss from land, and its likely impact on aquatic SSSIs and damage to soil structure caused by poorly timed access for arable operations. Conversion of ridge and furrow to arable would also destroy historical landforms to the detriment of the wider landscape, but it is very unlikely that such operations would be permitted by NRW under the EIA (Agriculture) (Wales) Regulations.

A change from arable cropping has potential to deliver significant environmental benefits, whilst still economically benefitting the farmer. Environmental benefits might be delivered through abandonment of modern drainage and a reversion of arable land to less intensive pasture-based production. Outputs from the system could be of high quality fodder for horses or livestock production within the UK's new Geographical Indication scheme.

Continuing arable production in the Levels is likely to require significant investment in either drainage or reversion that would place an exceptional financial burden on farmers and provides an opportunity for change to be influenced by changes in the developing farm payment regime.

Dairy

Dairying has historically been the largest agricultural sector in Wales, but the number of farms with dairy cows in the area declined by in the region of 20%, and the number of dairy cows by 55% between 2002 and 2018[3]. This is unlikely to represent a decline in the size of dairy farms in

[3] https://gov.wales/agricultural-small-area-statistics-2002-2020

the area, more likely the loss of relatively large units emphasising the polarisation between larger more intensive dairy units, of which there are at least two in the area, and smaller, less intensive units.

The primary drivers in dairying are to increase returns either by increasing the volume of milk produced from a fixed area of land or producing an output that can be used to add value by either direct selling or processing into yoghurt, cheese or ice cream on or off the farm.

Milk production is generally increased through herd management, breeding, environment or feeding. Performance related to feeding can be driven by forage production or grazing, both of which can be improved with drainage.

Drainage would also ease the growing of maize for forage, however on such a naturally wet landscape such as the Gwent Levels maize can be seen as an inappropriate crop to be grown, with the risk of running into the wetter season when access to land is limited by poor ground conditions.

Given the marginal nature of maize growing in the area, dairy farmers might consider other sources of forage such as herbal leys or more simple ryegrass/clover mixes and how these might reduce inputs and fit with other, specialist forms of milk production. The effective mitigation of risks associated with land access without recourse to land drainage but with lower costs and a different market for milk and dairy products may produce a better financial outcome than under the current risky management system.

Beef and sheep

Beef production is the second highest value contributor to Welsh farming output although lowland beef and sheep production has seen a decline in recent years[4], mainly driven by low cattle prices.

Beef production has been a mainstay of the farming sector in the Levels for many centuries and numbers were the same in 2018 as in 2002, although numbers did increase by about 50% for a short period between 2003 and 2011. The numbers of sheep in the area increased by 24% between 2002 and 2018 and the number of farms with sheep decreased by 10%.

[4] https://gov.wales/sites/default/files/statistics-and-research/2021-03/farm-incomes-april-2019-march-2020-914.pdf

Sheep farming generally achieves minimal returns on investments[5], with low sale prices and the costs of labour, feed, pasture management and housing often leading to negative net margins. This means that some sheep farmers rely on contributions such as the basic payment scheme. Top producers can achieve far greater returns than low achieving producers suggesting that efficiencies can be achieved to improve sheep farming profitability.

The primary drivers in beef and sheep production are stocking rates, pasture quality, animal health and liveweight gain, which can all be influenced by drainage in wetland areas such as the Gwent Levels. The silty clay soils of the area support consistently good grass growth, even in prolonged dry spells.

However, there is a limited time period when access to grazing is possible without causing soil damage.

Drainage creating drier ground will influence the worm burden on the grazing area which will have a positive impact on the health of animals.

[5] https://businesswales.gov.wales/farmingconnect/news-and-events/technical-articles/factors-affecting-sheep-flock-productivity

B Farming benefits from reduced surface and soil water levels

A key element in the performance of grass-based livestock or arable cropping systems is soil moisture status, with drainage playing a key part in achieving this in heavy soils. A good soil moisture status improves productivity, enables better access, and the growth of a wider range of crops, as well as improving soil workability, trafficability and uptake of nutrients.

The environmental and farming benefits of drainage can include:

- increased organic matter storage through increasing rooting depth[6];
- improved germination, yield and quality of crops[7];
- faster warming of soils, improved environment for soil organisms, better plant root access to water and oxygen and better fertiliser uptake;
- better access to land due to reduced waterlogging allowing better timing of crop inputs, including fertiliser and pesticides;
- improved work rates and reduced fuel use through fewer cultivation passes, fewer wet areas to avoid, reduced wear and tear, and better traction;
- better livestock health with lower worm burden;
- reduced risk of soil contamination during forage harvest

From a farm business perspective, the benefits of drainage can be simply expressed in terms of increased profitability, through improved crop yields, different cropping or improved animal health. For example, hay production ranges from a lowest expected yield (22t/ha) on poorly drained soils, with limited access and where good hay is difficult to produce, to a highest expected yield (up to 32t/ha) on the good, well-drained soils, an increase of 45%. Whilst it is acknowledged that higher yields for any crop (hay or arable) require more inputs, soil quality and the ability to access land are the foundations of productivity and farm profitability.

The full assessment of costs and impacts of land drainage on farming are detailed in Appendix 1 but it is concluded that on balance drained land would normally result in a positive return through improved yield, farm operations, flexibility and practices. However, capital investment

[6] https://www.nature.com/articles/srep45635
https://www.nfm.scot/sites/www.nfm.scot/files/CRW2014_03%20Final%20report_0.pdf
[7] https://ahdb.org.uk/drainage

in land drainage is not a straightforward decision and one or a combination of more of the following factors should be considered.

The Rigare report confirmed that very poor lateral water flow in soils is the main factor limiting the success of any land drainage system. Poor lateral flow means that drainage systems need dense network of relatively deep, gravel topped pipes overlain with well-maintained mole drains to minimise reliance on water flow through undisturbed soils. This type of system requires significant capital investment, which in turn requires high returns for it to be economic. Such high returns are unlikely to be achieved in pasture-based farming systems such as those found on the Gwent Levels.

Where decision making is based on the period of payback, which varies significantly from farm-to-farm, an extended payback period may result in drainage not being installed, for instance, where there is no succession on the farm and the current farmer is near retirement. Examples of payback periods are set out at Appendix 1.

Decisions may also be based on simple improvement in gross margin performance, although it is more difficult to make accurate forecasts for complex rotations than for straightforward forage production or simple grazing systems.

Historically though significant investments in drainage have been associated with incentives from government or private investment to increase production and land values. Similar strategic drivers toward more sustainable farming methods, nature and landscape recovery may be incentivised to improve specifically the Gwent Levels, or the development of soil carbon code similar to existing Woodland and Peatland Carbon Codes.

The following examples set out the benefits likely to accrue from the installation of land drainage and consequential change in gross margin, as opposed to the maintenance of the field ditches. The detailed calculations to provide the data underpinning these examples are set out at Appendix 1.

Common assumptions to all of the examples are shown in Table 1.

Cost of underground drainage - Small area	£4,560.00/ha
- Large area	£2,250.00/ha
Mole drainage	£75/ha
Maintenance of underground drains	1% of capital cost, annually for life of the project
Restoration of ditches	£20/m

Table 1: Common cost assumptions used in analysis of benefits

Example 1 – Undrained dairy

The first example is of a 250ha grazed dairy farm which has several undrained fields of varying sizes of around 10ha with wet areas, each with poor productivity and limited access, which would be drained using trenchless technology.

The benefits associated with drainage would be to bring the isolated areas into line with levels of accessibility and productivity of the rest of the block. The benefits of this type of selective drainage go beyond increased output to allowing management of the area as a single block, which is accounted for here by excluding additional costs associated with increased output.

Costs	£2,250	Payback period
Benefits	£164	14 years

Table 2: Payback period for drainage of land for silage production

The payback period for land drainage in this example is relatively long and may not be feasible on a large scale.

Example 2 – Undrained small-scale arable

The second example is of a farm with improved marginal land for wheat grown on small fields with no residual ridge and furrow features, typical of much of the area. On the assumption that yields from undrained land would be 20% less than from drained land producing average yields and that variable costs would vary with production, the additional gross margin amounts to £291/ha, from which has to be deducted the additional costs of harvest and an allowance for maintenance of the system. If the reen system requires renovation, then the additional costs of works should be subtracted from the residual benefits.

Costs	£4,560	Payback period
Benefits	£291 - £46 - £41 = £204	22 years

Table 3: Payback period for drainage of land for low output winter wheat production (small parcels)

Once an investment in land drainage has been paid off the benefits will continue for up to 30 years in this case, provided maintenance is sustained. The initial payback period in this case is long and it is unlikely that any landowner would consider any investment.

In this case the extended payback period makes it likely that marginal land would not be drained but left as grassland with wet areas for habitat, which action may attract payments for ecosystems services and enhanced natural capital valuation.

Example 3 – Undrained large scale arable

The third example is of the same farm as Example 2, with improved marginal land for wheat grown in fields of more than 10ha. Based on the same assumptions, the additional gross margin still amounts to £291/ha, from which has to be deducted the additional costs of harvest and an allowance for maintenance of the system.

Costs	£2,250	Payback period
Benefits	£291 - £23 - £22 = £246	9 years

Table 4: Payback period for drainage of land for low output winter wheat production (large parcels)

In this case, due to the lower costs associated with draining large fields, the payback period is shorter, with a longer benefit period after the initial payback. This option may be considered economic by some but a diversified non-arable option such as the production of haylage for horses may be more viable and not require a piped land drainage system.

Example 4 – Drained small scale arable

This fourth example is of a small arable farm with a poorly maintained drainage system resulting in the appearance of wet patches that prevent drilling and use of herbicides for weed control. This has resulted in patchy crops, an increased weed burden and soil damage.

Rather than renew drainage across the farm, selected problem areas could be drained to improve performance in particularly poor areas, reducing the capital burden and maximising opportunities for improved returns. The cost of drainage would be at the lower rate because of the total area likely to be drained in large fields.

Costs	£2,250	Payback period
Benefits	£291 - £23 - £22 = £246	9 years

Table 5: Payback period for small scale arable land

The outcome of the restoration of drainage to limited areas of poorly drained land is the same as in Example 3 above but the overall investment will be smaller since much of the farm already benefits from working drainage increasing the likelihood that works would be carried out.

Example 5 – Drained large scale arable

This example is of an arable farm already producing average yields with 50-year-old maintained drainage that is becoming less efficient. Fields are of 10ha or more and producing above average but declining yields. Assuming that variable costs would vary with production, the additional gross margin amounts may be up to £200/ha, from which has to be deducted the additional costs of harvest and an allowance for maintenance of the drainage system.

Costs	£2,250	Payback period
Benefits	£200 - £23 - £22 = £155	17 years

Table 6: Payback period for large scale arable

Here, the original drainage system, (probably funded with grant aid), has historically boosted yields and the farm infrastructure has adapted to an enhanced performance. In the absence of grant aid the cost of restoration of drainage to its optimum performance, should have been accounted for in long term planning and the ideal time at which investment is made decided. As yield declines and the cost of installation increases to reflect inflation, a point is reached where the payback period is reasonable, and an investment could be made.

Example 6 – Maize for dairying

It is clear from the experiences of some farmers that maize is at best a marginal crop in a naturally wet area such as the Gwent Levels. Where maize has been grown in intensive rotations it is likely that soil structure will have been compromised. The land would best be rehabilitated by implementing a long-term management strategy to restore soils. The improvement in soils could be very slow with minimal returns and very slow recovery that may take up to between 25 and 30 years.

Damage done to soils by maize growing is likely to be long term, mole drainage of damaged soils may provide a means to accelerate recovery of structure. A combination of legume, brassica and grasses in rotation to improve soil structure to depth, and restore carbon lost to anaerobic conditions.

In the short term drainage could be installed to improve cropping.

Costs	£2,250	Payback Period
Benefits	£595 - £23 - £132 = £440	5 years

Table 7: Payback period for maize production for dairying

The returns from improved maize yields are attractive although the exercise cannot be considered in isolation, and the inclusion of cereals for forage or feed, and grass in a long rotation would reduce the payback period. However, it would be necessary to drain in the region of between four and five times the area of maize grown in order to make the improvement throughout the rotation increasing the payback period for maize alone significantly.

With the continuing uncertainty over accessibility after harvest maize remains marginal in wetland areas, it is considered that maize growing on the Gwent Levels will reduce to very low levels or even stop altogether.

Example 7 – Hay production for forage

Specialist hay production for the domestic, equestrian markets and farmed livestock is an established and growing market in many areas. Whilst grass-based forage crops are deep rooted and thrive in areas such as the Gwent Levels, that have soil moisture reserves reducing vulnerability of crops to drought, they can also benefit from land drainage which can improve accessibility and thus yields and quality.

Costs	£2,250 - £4,560	Payback Period
Benefits	£398 - £23/£45 - £132 = £243/£221	9 – 20 years

Table8: Payback period for hay production

The tangible benefits of drainage to hay production are reliant on the cost of drainage works rather than returns alone, and the extended payback period for installations in small fields make the exercise uneconomic in most situations. However, specialist hay production also benefits from large fields where equipment can work quickly to fit harvests into often tight weather windows. A particularly good example of hay crops grown on heavy soils can be found in the Carse of Stirling, where specialist industry supplies very high quality forage to sport horse establishments throughout the UK.

Summary

The benefits of drainage to farming are clear in terms of improved outputs and land access for arable and pasture-based husbandry, but when related to payback periods the economic returns aren’t generally attractive for relatively low value crops such as grass. Few farmers are willing or able to justify a significant capital outlay that has a limited life and requires ongoing maintenance. It is cheaper to buy more land to achieve a similar increase in output.

'Spot' drainage of small, wet areas may be economic where they improve access and soils significantly and bring unproductive patches of land up to the workability and accessibility of the rest of a field. On the other hand, extensive drainage of large blocks where improvements due to drainage are marginal, across a large part of the drained area, are unlikely to be economic.

Extensive areas of the Gwent Levels are not hydrologically well-suited to piped drainage that requires associated mole drains because of limited freeboard between water and ground levels; therefore, it is probable that economically sustainable drainage would be difficult to achieve and likely that demand will be low.

C A Vision for Future Drainage and Land Management.

The range of repercussions of individual farmer's interactions with the drainage network on their own farm and on the whole drainage network is evident from a visit to the area and the aerial photographic record. The uncertain environment in which farming operates today means that most farmers are looking to increase productivity or diversify in order to remain competitive and stay in business. Coupled with the risks that ill-considered agricultural intensification and associated drainage works may result in adverse changes in the aquatic ecosystem, it is imperative that a clear and effective inclusive framework is established and advice available to allow farm businesses to develop in sustainable ways. These provisions should not only secure farming futures but also protect and enhance the natural environment of the Gwent Levels for the benefit of all.

This collective responsibility is best developed by a group of stakeholders who recognise their own and support others' critical roles in achieving the overall objective of a thriving landscape that can deliver a wide range of ecosystems services and so advance its own natural capital value in a sustainable way. The involvement and continuation of respected farming and landholding stakeholders in the IDD Advisory Group, where well-informed pragmatic and agreed solutions can be reached to the problems facing drainage in the area. These problems include the inability or unwillingness of some riparian owners to engage with the drainage system to maintain it in proper working order.

In order to be effective, any authority needs to understand how best the land and its drainage network can be managed to deliver the agricultural and environmental outcomes necessary to support a living landscape. Eco-hydrological investigations carried out as part of this project to some extent support assertions that land drainage does not have an adverse impact on the general hydrology of managed wetlands. However, the feasibility of installing an agricultural land drainage system with overlying mole drains in an area where there may be inadequate freeboard to allow drains to operate without risks to water quality and the longevity of the system itself, has not been established.

The developing framework of water protection regulation in Wales provides an opportunity to mitigate the impacts of fertiliser and pesticide use, on the water environment in proportionate ways; and requires farmers and land managers to maintain records of activities to demonstrate compliance. The wet environment that underpins the essential character of the area imposes challenging conditions on land managers and land drainage alone is not a panacea to farming problems.

All stakeholders have to recognise the environmental limitations and vulnerabilities of the area, as do the solutions that are advocated and adopted. Robust scientific research findings should be directly available to support decision-making processes, and these are often provided within the framework of an easily accessible knowledge hub. Not all stakeholders will have the capacity to engage with this resource or willingness to participate in the process of sustainable development. Often, the proportion of the total number of stakeholders in this group can be as little as 15% by number or land area, and thus can pose a threat to the success of an initiative.

To encourage this coordinated approach, it is recommended an integrated vision of land management in the Gwent Levels vision is developed, based on the findings of the Sustaining the Gwent Levels project and other projects, and ongoing stakeholder engagement. Only in the knowledge of a set of objectives for land management can the key steps to achieving agreed outcomes be determined. The result of this work should be a Gwent Levels management plan, which should consider the use of financial incentives to support its objectives, including support or compensation for actions that are beyond the statutory obligations of beneficiaries.

The responses of stakeholders who have engaged with this review of land management and drainage review has been encouraging but it is evident that there are significant financial barriers and differences in position to be overcome. The next steps should include wider stakeholder engagement with the specific aim of confirming and driving forward the vision that has come out of the Living Levels Legacy Programme and the Sustaining the Gwent Levels project.

It is anticipated that wider stakeholder engagement and the understanding of and involvement with the system will precipitate acceptance by some stakeholders that intensive drainage is not generally possible across the area. The need of farm businesses to adapt and effective communication with stakeholders should allow the limitations facing individual land parcels to be recognised and encourage the adoption of sustainable, nature-friendly farming, diversification into low intensity agriculture and the growing of crops better suited to the local environment.

4 Conclusions

The intensification of farming and amalgamation of farms and land parcels in the area after WW2 has not been simple or consistent. Consequently, the need and desire to maintain the drainage network is no longer uniform across the area as the costs of works have become disproportionate for smaller farmers with lower output.

Some larger fields have underdrainage installed, but its effective operation is reliant on a working network of closely-spaced mole drains overlying the piped system to overcome issues with poor lateral flows. Mole drains (See Appendix 2) cannot be inundated, which will cause them to collapse, so it is important for them to function to maintain vertical separation, freeboard, between water level and the mole drain. This is not always possible when the water levels in the reens are at a high level. An effective drainage system is reliant upon an informed holistic approach common to all riparian owners, and this approach has, in the main, been lost in the area.

However, agriculture is at a crucial flux point with changing demands from a variety of stakeholders pulling between food production and biodiversity benefits, which have until recently been perceived as polar opposites. The Gwent Levels demonstrate that this is not the case, the two are interdependent. The Levels are an agricultural ecosystem where the loss or compromise of the surface drainage network would severely damage farm businesses and destroy the unique aquatic habitats that the area supports.

The future direction of Government policy can provide opportunities for a more collaborative approach to a more sustainable system of managing the Gwent Levels. This should be stakeholder-centred with all riparian landowners and managers working towards a common approach to drainage. For any solution to work, a holistic approach to the drainage network should be taken with a managing body based on the existing IDD Advisory Group working for the benefit of all stakeholders, incorporating a sound understanding of the unique ecological and drainage characteristics associated with the Levels. Such a body could oversee the distribution of funds to support the maintenance of the drainage system and clear those watercourses which have been neglected, using a carrot and stick approach.

The costs of underdrainage relative to increased returns likely to its installation are significant and may be regarded as capital expenditure. The return periods on such high cost expenditure are lengthy and drainage is significantly more economic where high return and intensive crops such as cereals and maize are grown. Whilst the risk of soil damage or harvest loss attached to growing maize are significant, drainage for cereals has a more sustainable outlook and renewal of drainage systems may be justified where they have reached the end of their working life.

Historically, most drainage systems have been installed with grant aid under government programmes to increase output, similarly today government programmes are in a position to drive production and environmental agenda and the use of aid is likely to be critical in the conservation of the Gwent Levels and agriculture's role in it.

In future, the farming systems pursued by farmers will therefore not only be dictated by market returns and provision of payments or grants for environmental services and goods. For any mechanism to be successful, there needs to be a balance between drivers and incentives guided and informed by a body that can effectively disseminate the findings of relevant research via an easily accessible knowledge hub accessible by all farmers.

It is anticipated that with understanding of the system will come acceptance by some stakeholders that intensive drainage is not feasible across the area, at least within economic and hydrological limits. That recognition of constraints will assist the promotion of sustainable, nature-friendly farming and diversification into low intensity agriculture and the growing of crops better suited to the local environment.

Appendix 1 – Financial Analysis (for section B above)

The worthwhileness of piped land drainage in a range of situations has been assessed by way of an analysis of simple economic surplus when costs are subtracted from any increase in benefits likely to accrue from its installation.

The costs of drainage works can vary significantly between fields and farms, according to the condition of the land and ditches, and the freeboard between ditch water levels and the field surface. Costs for any works necessary to rehabilitate wet drains or reens are not included in this analysis. Benefits will also vary from farm-to-farm, dependent on the size of the farm, cropping and any realisable economies of scale, farm prices, the proportion of the farm that is drained, herd/flock management and agronomy, as well as husbandry generally.

A justification for drainage is outlined in Appendix 4 and costs are discussed and described below.

Assumptions and Variables

In order to assess whether drainage is economical, and in the absence of any detailed assessment of the freeboard available for drainage in any part of the Gwent Levels, this report assumes that this is the case and deals with the underground drainage of land parcels on the assumption that whole drainage networks are in good condition. Where parts of the network are not in good condition, the operation of land drains will be compromised and therefore likely to be ineffective.

Where there is insufficient freeboard and the mole drains associated with a piped drainage system are liable to be flooded, a piped drainage system is likely to be unsustainable.

In order to undertake a comprehensive assessment of the economic benefits of land drainage in the Gwent Levels it is necessary to consider the length of grazing period as well as simple crop yield. This also includes any increase in the range of crops that can be grown.

For the purposes of this study benefits associated with drainage in turn split into benefits to livestock and benefits to arable farming. Benefits to livestock farming are not restricted to increased yield of forage, reduced poaching risk on drier soils can increase the length of the grazing season and have benefits to palatability, animal health and animal cleanliness. The relationship between increased grass or forage production, and length of the land access period and farm income is complex due to the interaction of a number of variables, this is developed in the scenarios below.

Length of grazing season and weight gain or milk yield in cattle can be linked to poaching control and studies across the UK have found that the grazing season can be lengthened between six and 11 weeks in a year with drainage[5]. This not only saves the purchase of feedstuffs or conservation of silage but also may result in better quality silage and an earlier opportunity for first cut and additional later cuts, bringing associated economic benefits.

Higher incidence of animal disease and foot rot can also be associated with wet pasture[5] although the greatest benefit from drainage is possibly the reduction of liver fluke through control of the host snail and the destruction of its habitat. While cleanliness of stock is more difficult to quantify in financial terms beef and sheep encrusted in mud generally have lower value or be rejected at the abattoir, and a mud-caked dairy cow will require more preparation time in the parlour.

In arable agriculture the benefits of drainage are related to the better yields associated with increased use of fertiliser, nitrogen and improved strength of soils to carry machinery, reduced wear and tear on machinery and workability of soils.

Drained soils allow better development of root systems that sequester carbon to a greater depth in intensively farmed mineral soils where organic matter levels can be low. Increased emissions of greenhouse gases associated with drainage are generally derived from organic and peat soils, which have limited distribution in the Gwent Levels. Of greater, albeit incidental, concern with regard to greenhouse gas emissions are those associated with poorly-maintained (anoxic or eutrophic) surface drainage systems, which may exceed emissions from well-maintained ditches and reens and cancel out any benefits associated with drainage[8].

Wet soils also result in increased draught forces and higher operating costs and emissions from machinery, as well as increased risk of damage to soil structure. Drier soils improve workability resulting in better seedbeds and an increased range of crops that can be grown.

The economic landscape within which farming operates holds many long term challenges: adaption to and mitigation of climate change; introduction of new technology, such as robotics and data applications; the replacement of an aging workforce; and the uncertain yet significant policy and market changes that come with Brexit. Each farming business will be impacted by these challenges and will react in different ways, and this uncertainty is complicated by the diverse nature of those businesses making it difficult to predict the current and likely future level

[8] M Peacock et al 2021 Environ. Res. Lett. 16 044010

of business performance, but also to impose any common method of assigning interest, amortising costs or treatment of capital.

In the light of significant variations between farms and farming businesses on the Levels, the following assumptions have been made in the analyses:

- no account is made in the analysis for interest charged on any loan or discount rate;
- the surface water drainage system serving the area to be drained is fully functional and requires no improvement;
- that farm businesses will continue to invest and compete actively in the market;
- that there will be an orderly Brexit process and so commodities prices will remain stable
- the fixed costs of individual businesses are comparable with others in the sub-sector in which they operate; and
- a common level of ability and mechanisation within sub-sectors.

Ultimately, farm businesses will react to the environment in which they operate and in the light of particular circumstances, which may not reflect the simple likely economic outcomes set out in this report.

Standard values and costs for outputs and inputs are taken from the most recent editions of the John Nix Pocketbook, the Agricultural Budgeting and Costing Handbook and the SAC Farm Management Handbook. Where standard figures are not available or they varied significantly from known local costs, specialist contractors have been approached and specific local figures used.

Cost of underground drainage

This exercise assumes that the land to be improved has no existing underground drainage system or that any system that might exist is redundant through lack of maintenance and requires total replacement.

A summary of costs is set out in **Error! Reference source not found.**. Drainage costs and work rates vary considerably with specific site conditions and requirements. The figures used in this report are indicative only and estimates for the likely cost of work in specific circumstances should not be based on them.

Operation	Outcome	Cost	Unit
Install land drainage	Small area drainage using backhoe. 850mm – 1,200mm depth. 20m spacings with gravel backfill to 400mm from surface Large Area drainage using trenchless machine. 850mm – 1,200mm depth. 20m spacing with gravel backfill to 400mm from surface	£4,560 £2,250	/ha /ha
Mole Drainage	75mm diameter mole drains at 3m spacing (DIY) 75mm dia @ 3m spacing (contractor cost)	£55 £100	/ha /ha
Maintenance	Annual maintenance annualised	1% of capital cost	
Gripping[9]	Standard form 100mm deep 150mm – 200mm deep Distribute excavated spoil	£1.00 £1.50 £0.50	/m /m /m
Rotary Drainer	Restoration of grips and furrows and spoil spreading	Quoted only	
Mole Ploughing[10]	Single leg mole ploughing (contractor) (farmer)	£88.00 £63.00	/ha /ha

Table 9: Summary of Drainage Costs

Following consultation with drainage contractors the most suitable system for conditions in the Gwent Levels is based on drainage laterals at a minimum of 850mm depth spaced at 20m overlain with gravel backfill to aid drainage. The design life of the system is estimated at 50 years, with maintenance. Drains in the Gwent Levels are likely to be most effective where the outfalls from drained parcels have an invert level above the maximum standing water level in any receiving ditch. Gravel backfill should be installed to between 400mm and 550mm (max) of the soil surface. Mole drains should be installed to intercept gravel backfill.

The cost of supply and installation of drainage systems also varies according to the area covered. In the case of small areas and/or small fields the cost is significantly greater than for a relatively large area spread across large fields; this is driven by combinations of the machinery used for installation and comparative work rates. In the case of a small area of 3ha, installed using a backhoe or tracked digger the budget cost would be in the region of **£4,560/ha**, that is £91.20/ha/year given a 50 year construction life. For 20ha of drainage with long drainage

[9] Pers. Comm. RSPB
[10] John Nix Pocketbook 52nd Edition (2022)

laterals, installed using a trenchless machine, the cost would be in the region of **£2,250/ha**, that is £45/ha/year given a 50 year construction life.

In order for the system to be effective, the drained area of any size should be mole drained to intercept gravel backfill at three metre spacings at a maximum seven year interval. The frequency of mole draining will be dependent on land use and particularly the use of heavy machinery on the land. The risk of destroying mole drains associated with machinery use are significant and the frequency of renewal may by increased too triennially. The cost of mole draining will vary according to the depth of installation, which influences work rate and whether or not a contractor is used, which will have a higher cost. The range of costs for mole drains is between **£55/ha** and **£100/ha**, that is between £11/ha/year and £20/ha/year for an average life of five years for mole drains.

Cost of traditional surface drainage

Ridge and furrow systems in the Levels often have crossing, second order furrows to convey water more directly to the ditch system than along a single long furrow. Second order furrows (called grips locally), sometimes have a secondary ditch measuring approximately 100mm wide by 100mm deep, running in their base connected either directly to a wet or dry ditch or by way of a length of underground drain running under raised banks along ditch lines. These grips are excavated and provide an immediate vector for surface runoff from fields direct to perimeter ditches and an associated risk of phosphorus and silt transmission to surface waters.

Some farmers, instead of digging an open ditch to assist drainage install one or more mole drains along second order furrows. This provides a less direct route for drainage from fields but has the advantage of mitigating the loss of nutrients and sediments from land by holding them in the field. In crop-based ridge and furrow systems, this accumulation is ploughed out from the furrow back onto the ridge, which in a pasture system might be accomplished using a rotary drainer such as that used to excavate foot drains to spread arisings on ridge tops. The resulting scrapes have potential to provide temporary wet habitat for colonising plants and wading birds or they can be reseeded.

Fig. 3 - RSPB Rotary Drainer excavating a foot drain – the depth and width of the feature and spoil spreading can be adapted for use in the restoration of grips and furrows.

Gripping can cost in the region of £1.00-£2.00 per metre plus costs for any piped infrastructure that might be necessary. It is difficult to budget an 'acreage' cost for the operation, which would include mobilisation of machinery, but it is likely to be up to £650.00/ha.

The restoration of ridge and furrow land may also be contemplated, and it is understood that this may be accomplished in a single season using a rotary drainer, although it is likely to be more effective to restore the landform over time using managed ploughing techniques, as has been the case historically.

The cost of restoration of ridge and furrow would be likely to be in the region of **£1,950/ha** with reseeding with a rotary drainer, or an additional **£290/ha** every three years for 18 years with a plough as part of a conventional rotation, giving **£2,030/ha**, with reseeding.

Returns from benefits accruing from drainage

The benefits accruing from the presence of land drains vary according to the use to which land is put. Estimation of the value of the likely benefits of land drainage is complex and historically controversial, since payback is more often than not dependent on the value of outputs to a specific business and overestimation is easy.

The benefits of drainage envisaged by farmers and landowners tend to relate to extending the grazing season, and access, although the recent Rigare hydroecological study concluded that in some grassland areas without intensive mole drainage there was no benefit in length of grazing season. Graziers understand that once land is wet it is not suited to grazing, stock have to be moved, and waterlogging is an increasing risk with climate change. UKCP18 projects an increased risk of more intense rainfall events when summer rainfall does occur, although precipitation is projected to fall, with wet summer days becoming less frequent overall. This is likely to result in waterlogging and surface flooding in some areas and may affect access to land for grazing.

The impact of these events can be mitigated by ridge and furrow landforms and associated grips or foot drains. These features also help extend the grazing season for livestock because water accumulates in the low-lying areas, although this works better with low stocking rates. High stocking rates still tend to result in poaching in saturated areas. Lighter stock such as sheep or young cattle are also well suited to extended grazing in these areas, although fluke risk is high on wet ground.

Arable farmers and livestock farmers growing maize or with short leys gain benefit from extended and/or better access for drilling and cultivations. Planting a cover crop or reseeding after maize harvest, is often not possible because of a late harvest, so the ground is left open all winter and leads to runoff.

More farmers are giving up maize because it creates a mess in the fields & roads. Some farmers in the area view annual returns of £3,750/ha (£1,500/acre) rental income for solar panels more attractive than farming.

Wet hedges are useful, but where the water level is within reach of livestock, as can be seen in Figure 4 which is of a main reen, stock will access the water for drinking and fencing is necessary to prevent erosion of banks.

The grips are partly helpful for keeping livestock out later if they are low stocking rates because the water gravitates off the grazing into the dips, but if the stocking is high there is a risk of poaching and banks to collapse. Lighter stock such as sheep or younger cattle are more suitable but can still damage banks.

Figure 4: Comparison of water level and fencing type

The return on arterial drainage of agricultural land depends on parallel investment in field drainage by the farming community. Throughout the inter-war period the economic condition of agriculture was not conducive to field drainage investment, and little was carried out, but after WWII government's drive food security resulted in heavy investment driven by grant aid, which ceased in the 1980s. Since the end of grant aid, few large land drainage schemes have been implemented and often systems have been taken for granted, forgotten and neglected.

For the purposes of this report, it is convenient to express benefits accruing from the installation of land drainage in financial terms. Because of the complexity of farm budgeting, which can vary considerably from farm-to-farm with a farmer's attitude to finances and the environment, history, infrastructure and available natural resources, a 'gross margin' is often used as a comparator for farm business outcomes; this approach underpins the analysis.

The gross margin of an enterprise, be it at whole farm, crop or field scale, is its gross income less the variable costs incurred in achieving it. The calculation does not include fixed or overhead costs such as depreciation, interest payments, rates, or permanent labour. Gross margins are intended to provide a guide to the relative profitability of similar enterprises in differing situations and an indication of management operations involved in different enterprises.

The examples below are illustrative and based on standard costs, and the changes in gross margin, they are used to illustrate the financial benefits likely to accrue from the installation of drainage in a variety of examples representing farms in the Levels.

Arable

The calculation in Table 10 illustrates the likely improvement in gross margin for wheat, with the installation of land drainage. The average yield of 7.96t/ha is based on UK yields 2016 and 2020 on improved land. It is also assumed that poorly drained land in the Gwent Level would produce 20% less yield. Despite being poorly drained, it is estimated that baseline production would require 10% more fertiliser and 10% more crop protection.

Table 2: Gross margins for winter wheat production

		Undrained soils with failing mole and surface drains		Improved soil drainage
		Yield -20% Fertiliser +10% Crop Protection +10%		Average UK yield
Yield		£/ha		£/ha
	Sales	992		1,240
Output/ha		**992**		**1,240**
Variable costs				
	Seed	57		57
	Fertiliser	229		208
	Crop Protection	242		220
	Sundries	25		25
Total Variable costs		553		510
GM		**439**		**730**
Improvement			£291	66%

Whilst it is likely that the majority of arable land in the area is already underdrained

Given a drainage cost of £2,250/ha on land suited to arable production, it would take eight years for the investment to be paid off. This would mean that an additional £291/ha/year would be generated through the remainder of the 40 to 50 year life of the system, that is between £9,300 and £12,200.

Dairy

Given the relatively small number of dairy farms in the area and the range of scale and husbandry practised, it is not possible to make any globally applicable assumptions. The example adopted is of a 250-cow dairy farm with limited grazing and growing maize, wholecrop wheat and grass for forage has significant problems with access to land for harvest at the end of the season causing significant soil damage. This example assumes that it is possible that working drainage with gravel fill and mole drains can properly be installed, which is not the case for some dairy farms in the area because of lack of freeboard.

By draining 10ha of wet land, including 350m of restored ditch, reliable production of grass silage can been restored with land left for grazing after a fourth silage cut.

Using an example from AHDB[11], it is estimated that forage yields would rise from 37t/ha to 45t/ha (25%), the value of forage increased by £4/t because of improved forage quality and dry matter content and the grazing period increased by ten days at the beginning and end of the year, this generated an increase in value of £490/ha. In addition, there were savings on cultivations to grow maize of £105/ha. Additional costs of £52/ha and £132/ha were associated with the ongoing maintenance of drainage and increase in forage production respectively. Thus, the net benefits of drainage amounted to £411/ha.

The cost of land drainage on the 10ha 'wet patch' were £450/ha for the restoration of 300m of reen and £2,250/ha for land drainage using trenchless technology, a total of £2,700/ha.

The cost of mole drainage is cancelled out by the need to subsoil the field after cropping on wet soils.

Thus, the investment in drainage would be paid off in seven years and would contribute to higher margins for the rest of its life of between 40 and 50 years with maintenance. This would generate an additional £17,600 to £18,000 over the design life of the system.

Table 31: Gross margins for diary (example taken from AHDB[13])

DIARY	250 cow dairy farm £/ha
Sales	490
Savings on fodder	105
Output/ha	**595**
Variable Costs Total:	**184**
Maintenance of drainage	52
Forage Production	132
Gross Margin	**411**

[11] AHDB Drainage Guide

Whilst this improvement in performance is attractive it is imperative to bear in mind that key factor in the Levels is that it is simply not feasible to install underground drainage to the necessary specification in most low-lying areas because of lack of freeboard to allow mole drains to function effectively.

The Rigare report confirms that lateral flow throughout the soil profile is severely impeded and in order for drains to be effective in these circumstances it is necessary to install gravel-covered drains with outfalls below the standing water level in the reens. However, piped drainage systems will not be successful in the absence of an effective overlying mole drainage network, draining into the gravel fill. The mole drains would have to be installed at a minimum of about 0.5m below ground level, which in some of the areas that would benefit most from drainage would be inundated for part of the year; this would cause the mole drains to fail.

Beef

Beef production on the Levels ranges from suckler cow herds producing calves for their own and others to rear and finish, to specialist rearing and finishing units. This section examines the gross margins achievable in grass finished suckler calves, an element which can be carried out in isolation or as part of an integrated production system.

This analysis assumes an average stocking rate for well-drained land of 3.4 animals/ha. Drainage is expected to extend the grazing period by at least ten days before 15th April and ten days after 15th September in any year, that is 20 days extra grazing in addition to the current 153 day grazing period; a 13% increase.

It is also assumed that undrained land in the Gwent Levels would mean that to achieve similar output from the same area:

- 13% more concentrates would be required to compensate for the shorter grazing period; and
- poor soil conditions would limit stocking rates to 70% of those of well drained land, that is to 2.4 head/ha.

	Undrained soils with failing mole and surface drains	Improved soil drainage
	Stocking rate 2.4head/ha 13% more concentrates	Stocking rate 3.4head/ha (steers)
Yield	**£/ha**	£/ha
Sales	1,246	1,246
Less purchase	947	947
Output/ha	**299**	**299**
Variable costs/head		
Concentrates	25	23
Vet & med	14	14
Forage costs	75	75
Sundries	28	28
Total Variable costs/ head	142	140
Gross margin/head	**157**	**159**
Gross margin/ha	**377**	**541**
Improvement	£164/ha	44%

Given that the majority of beef production in the area is based on small fields, drainage would cost in the region of £4,560 to install, the payback period for drainage at this rate would be 28 years. This period is likely to be beyond the financial planning range of most farm businesses in the area and the investment would probably not be considered to be valuable to a farm business with a principal over 50 years of age.

Diversification – Specialist Hay

There is presently a developing market for the growing of hay for specialist domestic and leisure animal keepers, particularly of high quality haylage for sport horses and bedding/feed for small domestic pets.

The average yield of hay is between about 6t/ha and 8t/ha, with the higher yields possible on well-managed, drained land, which could also support aftermath grazing as part of a wider livestock enterprise or silage production[12]. Hay can lose as much as 15% of its weight in store over winter, but the weight of haylage is conserved by wrapping.

The Gwent Levels are well-suited to hay production because deep rooting grasses can take advantage of soil water up to two metres below ground and avoid the worst effects of drought on yield, and traditional leys can produce good yields without need for manufactured fertiliser.

[12] https://www.fas.scot/downloads/farm-management-handbook-2020-21/

An annual charge for reseeding at a rate of 13-18kg/ha is included in the gross margin calculation. Fertiliser application is limited but may take the form of surface dressing of livestock manure or digestate rather than manufactured fertiliser. Sprays may be used for control of broadleaved weed species including docks and thistles.

Table 13: Gross margins for specialist hay production

	Undrained soils with failing mole and surface drains		**Improved soil drainage – better access and aftermath grazing**
	5.8t/ha @£100/t		9t/ha @ £110/t
Yield	£/ha		£/ha
Sales	580		990
Aftermath grazing			40
Output/ha	580		1030
Variable costs			
Fertiliser	101		150
Maintenance	12		15
Total Variable costs	113		165
GM	467		865
Improvement		£398	85%

Example Mixed Farm

Taking the example of a mixed farm of 40ha, comprising 20ha of grass for grazing a beef herd, 10 acres of cereals and 10ha of grass taken for hay using the figures given above for gross margins £/ha.

Table 44: Gross margins for example 40ha mixed farm

EXAMPLE MIXED FARM	
Beef Gross Margin 20ha	10,820
Cearal Gross Margin 10ha	7,300
Hay Gross Margin 10ha	7,750
Total Farm Gross Margin:	**25,470**

The cost of draining 40ha of land, which on a farm where a trenchless machine could be used would be in the region of £2,250/ha, a total of £90,000. Given the improvement is consistent the payback period for the drainage is 10 years, not accounting for additional costs of maintenance of the drainage or additional management and machinery inputs. The cost of installing a system in small fields would be about double the cost and thus have a payback period of 20 years, excluding additional costs. It is unlikely that drainage would be seen as viable in small fields.

Appendix 2 – Types of Drainage

Agricultural land drainage[13]

Agricultural land drainage covers two closely related processes, the drainage of land parcels to lower the water table and improving the conditions for access and growing crops; and arterial drainage. In the Gwent Levels arterial drains provide capacity for the surface drainage network of ditches and reens to shift water from the land. The first process cannot function effectively unless the second is itself working, and the first cannot function as originally intended without all of the watercourses being in their original intended condition.

The productivity of soils depends on, amongst other things, there being adequate but not excessive amounts of water within the rooting depth of crops. Land drainage has been used to improve land and facilitate access to grow crops but it can also be a vector for eutrophying nutrients and agrochemicals to enter surface waters.

Well designed and maintained agricultural land drainage sets out to improve soil conditions by removing free water as rapidly as possible whilst retaining water for plant growth. Ideally drainage returns land to field capacity within 48 hours of intense rainfall, although it may take longer to dry soils sufficiently to carry traffic.

There are two physical aspects of soil condition that are improved by drainage: trafficability (access for machines and livestock), which applies to both arable and livestock farming; and workability, which applies more to arable farming.

Tracked and wheeled vehicles need to travel across soils with minimal risk of damage to soils, which may limit plant growth, and livestock trampling can cause lasting compaction damage that will limit grass growth, particularly under wet conditions.

Workability relates to soil tillage, which by cultivations provides a seedbed and rooting zone for crops but can be harmful when carried out in conditions that are either too wet or too dry. In wet conditions, which are most likely on the Levels, soil structure can be destabilised or soil surfaces smeared and structure damaged.

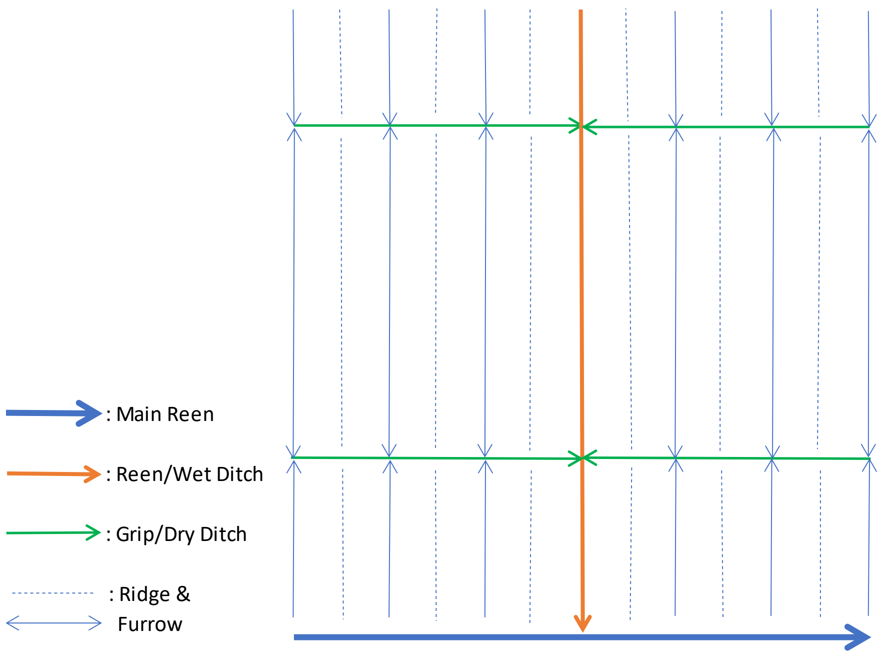
13 https://projectblue.blob.core.windows.net/media/Default/Imported%20Publication%20Docs/Field%20drainage%20guide%200818.pdf

Drainage design has developed greatly since the mid-nineteenth century when approximately more than 15 million acres across the UK were drained in about 40 years.

In common with much of the UK it can be assumed that a large proportion of 'improved' land used for arable and dairying on improved pasture was either drained before 1939 when between 25% and 50% of land in Monmouthshire was drained[14] or since the 1950s when government grants were available for drainage works. Parish data used in research carried out in 2011 suggest that between 12.5% and 17.5% of all land in the Gwent Levels was drained between 1971 and 1980[15].

Current Drainage

Recent underground systems work on a multi-tier basis similar to surface drainage (see **Error! Reference source not found.**5 and **Error! Reference source not found.** below). Reens take discharge from underground pipes laid out as a system of secondary header drains, wet ditches in a traditional system, and primary lateral drains, dry ditches or grips in a traditional system. In low permeability soils lateral drains would have to be laid at close intervals (3m) to be effective but instead are spaced out further (20m-30m) if installed with permeable backfill across which mole drains (ridge and furrow) can be ploughed to intercept soil water and help achieve relatively low soil moisture levels.



[14] https://www.bahs.org.uk/AGHR/ARTICLES/46n1a5.pdf
[15] http://nora.nerc.ac.uk/id/eprint/14118/1/ADAS-Defra_Drainage_in_DTCs.pdf

Figure 5:Traditional ridge and furrow surface drainage

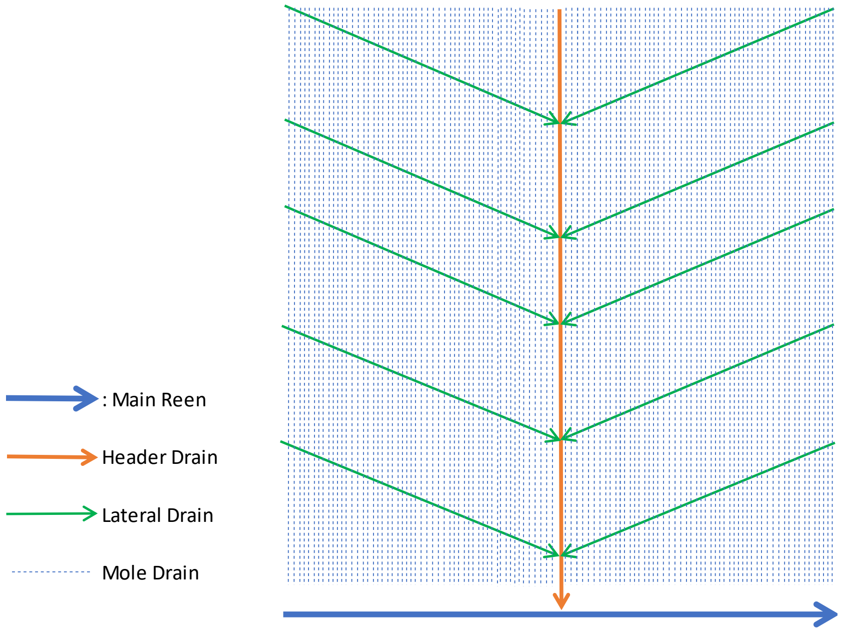


Figure 6: Modern underground drainage system

Therefore, although the modern underground system with overlying mole drains is more intensive and effective than the traditional surface drainage system, it requires a greater freeboard over surface water levels to ensure that drainage takes place without obstruction when ditch water levels are high.

Water does not drain from any soil profile until it is at Field Capacity and will continue to drain until the soil profile returns to moisture deficit. The drainage period, from return to Field Capacity until return to Deficit depends on summer rainfall and cropping. In some areas the drainage period can be estimated using the water holding characteristics of the soil, recorded rainfall and estimates of evaporation, including transpiration, from the field.

In periods when rainfall intensity exceeds the infiltration rate of the soil, which are frequent on heavy land such as the Gwent Levels, ponding occurs and on ground with any fall overland flow will start. The UKCP18 climate projection suggests that it is very likely that there will be an increase in the intensity of rainfall events which will increase the risk of ponding and overland flow, particularly in the summer grazing period.

In conditions such as those found in the Gwent Levels, where intense rainfall brings a significant risk of surface flooding, it may be that traditional surface drainage systems of ridge, furrow and grips will be more successful at maintaining access by removing water from land across the soil surface than underground drainage, which relies on first infiltration then percolation. Given summer soil water table levels observed by Rigare, it is unlikely that water in the soil profile will need to be replenished in the summer to maintain optimum crop growth because of the rooting depth of grass. On the other hand, cereal crops are shallow-rooted and cannot ‘chase’ a retreating saturated zone, as can deeper-rooting grasses.

The historical drainage design with complex ridge and furrow systems discharging run off into a surface drainage network, with appropriate falls and channel cross sections. Allows erosion to be controlled, with less silting easing maintenance and minimising soil loss from the fields using grips, that encouraged deposition of silt from run off. In the traditional system, grips have to be cleaned or furrows mole drained regularly, in order to maintain function. Although some farmers with such drainage systems have neglected to clean grips or restore mole drains every five to seven years, they are then liable to collapse naturally within that period. Refreshing mole drains can be as infrequent as every 12 years in situations where careful management avoids trafficking in periods when the drains are vulnerable to damage, but as frequent as every two years where there is intensive trafficking.

The term ‘grip’ can also be used to describe narrow, shallow open ditches excavated along the line and in the bottom of furrows, helping remove surface water from the system. These grips are linked into underground drains running across the grips, which in turn discharge into a wet ditch or reen. This system is similar to the traditional system of mole drainage in furrows described below, but can present an obstacle to trafficking. In time, the vertical sides of freshly-excavated grips collapse leaving a narrow foot drain in the base of the furrow.

The costs of grip cleaning and establishment, and regular mole drainage have to be taken into account in the economic assessment of drainage in soils such as those found on the Levels.

Whilst it is commonly believed that drains and ditches should be laid to falls, much successful drainage work is carried out on the flat. However, it is essential that dips in pipes (and moles) are avoided to reduce the risk of silting and where ground conditions are unstable, or the standard of laying inadequate, drains should always be laid to falls.

On the Levels, Rigare found that first order ridge and furrow spacings were between 6 and 8m and second order 20m, as shown in Table 1616.

Study area	NGR	Drainage	Notes	Gradients
Great Newra Farm	336100 184200	Traditional	Two order Ridge & Furrow to wet ditch 2nd order furrow connected by pipe under cast material along ditch bank top.	Cross R&F 1:50 - 1:100 First order 1:80 Second order 1:200
Cross Farm – Chapel Road	336430 183650	Traditional & underdrained	Two order Ridge & Furrow with land drains @ 600mm BGL and backfill over below 2nd order features. Mole drained @ 450mm BGL @ c. 3m centres along R&F. Water within 400 of surface intermittently at ridge tops but maintained at about 400mm by mole drainage in furrow and second order grips.	Cross R&F 1:20 - 1:30 First order 1:200 Second order level
Cross Farm – Nash	334900 183676	Underdrained	No visible Ridge & Furrow. underdrains with stone over mole drains. No new mole drainage for several years. No visible outfalls	Assume level(ish)
Fair Orchard Farm	329850 183900	Traditional	Two order Ridge & Furrow. 2nd order @ 40m spacing (v. wide). 1st order @ 10-12m. 2nd order drained to surface water by pipe after casting	Cross R&F 1:27 - 1:33 First order 1:70 Second order 1:200
Sluice House Farm	324900 179320	Underdrained	No visible Ridge & Furrow. Underdrains with stone over and mole drainage planned. No mole drainage for several years. No visible outfalls.	Assume slight dome

Table 16 Drainage characteristics of Rigare study areas

Ideally, land drains are placed as close as possible to reduce the need for lateral water in the soil profile flow between drain runs. Such intensive drainage is expensive, and systems have to be a compromise between benefits and costs of installation, generally related to the density and specification of the pipe network. Thus, agricultural land drainage in the Gwent Levels is most limited by lateral flow, which is restricted due to poor soil porosity as confirmed in the Rigare report, thus drainage networks have to be dense to be effective.

Maintenance

Every drainage scheme is only as good as its outfall and poor land drainage in some areas is likely to be due to poor management or neglect of ditches, especially in parts of the Levels where falls are poor or water levels high. Maintenance provides water storage, promotes flows that flush silt from pipe systems, traps sediment and reduces nutrient losses. Badly maintained ditches stop mole drainage working and where mole drains are submerged the whole system silts up. Where mole drains are saturated for long periods, which studies of water table levels in a parallel study suggest is the case, channels collapse sooner than they normally would.

Innovations in drainage design and installation have reduced costs and installations today are adapted to local conditions of climate, land use and soils, and a drain interval of 20m is feasible in the Levels, thanks to the use of a combination of permeable backfill over permeable pipes and regular intensive mole drainage.

Comprehensive land drainage systems such as this are not normally associated with land with ridge and furrow features, which relies on the surface falls shown in Table 1616 to remove a large proportion of rainfall from the field by surface run off before it infiltrates or pools on the soil surface. The use of piped land drainage and mole drains in the Levels is further limited by the freeboard between fluctuating surface water levels in wet ditches and the wider reen system and ground level.

Piped drainage requires adequate freeboard between the soil surface and the maximum water level in the receiving ditch to avoid silting up piped drainage laterals. Drains can be installed at as little as 0.75m depth, but where permeable backfill is used to serve mole drains at 0.4m Below Ground Level (BGL), and a fall is required under fields that frequently have dished surfaces or where drains require a fall, an absolute minimum of 0.85m BGL and more likely 1.2m BGL is necessary[5,16].

In many drained areas, including the Somerset Levels, Cambridgeshire Fens and part of the Gwent Levels, this is achieved by pumping from low to higher levels to reduce water levels in cultivated areas and deepening ditches to achieve adequate freeboard. Only three small parts of the Levels have pumped drainage, with the majority relying on gravity for discharge *via* 25 tidal flaps.

Piped drainage need not have any adverse impact on SSSIs provided systems are properly designed and installed, and land management is within GAEC and developing regulation, all of which protect waters from pollution associated with diffuse nutrients, pesticides and sediments.

In areas where fields are dished, or accumulations of silt from ditch cleaning have resulted in a raised field perimeter, as evidenced by darker areas in LIDAR images (Figure 8). Piped drainage has to be installed across headlands, to either assist discharge to the ditch system through or under a ditch bank that obstructs surface flow, or along headlands, in ridge and furrow areas. Where channels to assist drainage to ditches are excavated in the base of furrows, and they may be piped under banks this is termed 'gripping'.

[16] Pers. Comm. Rob Burtonshaw, Farm Services Ltd

Mole Drainage

Mole drains are unlined channels installed at two to three metre intervals, formed in clay subsoils using a single long-leg cultivator with a cylindrical foot and an expander that compact the channel wall. Channels should be at zero or consistent very shallow gradients to discharge water in either a gravel filled pipe drainage system or occasionally direct to a ditch, (see Figure 7). Mole drains are not effective if they become flooded, which causes them to collapse and need replacing.

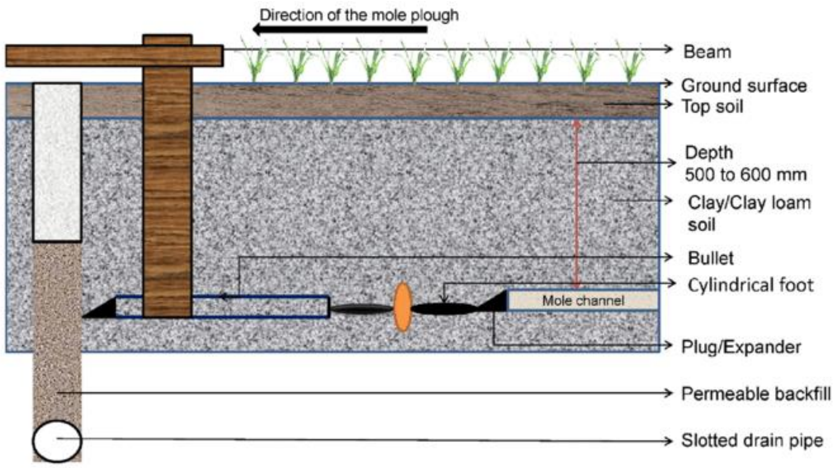


Figure 7 Cross section of mole drain installation[17]

The low cost of mole drainage means that it is possible for pipes to be installed at intervals as frequent as 2.5m (£60-£90/ha), so minimising travel distance from surface to drainage network.

Mole drains on ridge and furrow land should run along the bottom of furrows, and where ridges are widely spaced it may be desirable to install three mole channels in each row, one in the bottom and one about one metre on each side of the bottom. Surplus water runs off ridges and into the furrow where mole drains at between 300mm and 700mm deep and associated passages through the upper soil profile rapidly take water away.

Installation of mole drains should be carried out in soil conditions that are neither too wet nor too dry. As a mole bullet moves through the soil, it should leave a smooth channel and raise the ground either side of the coulter, creating fissures in the soil profile that run towards the main slot. In good conditions and with good management, the slot and fissures persist for many years re-opening in times of drought and allowing effective water from surface to the vertical slot and mole drain below.

[17] https://www.researchgate.net/figure/Mole-drainage-system_fig7_331040531 from Soil and Crop Management Practices to Minimize the Impact of Waterlogging on Crop Productivity. Nuruzzaman Manik *et al* (2019)

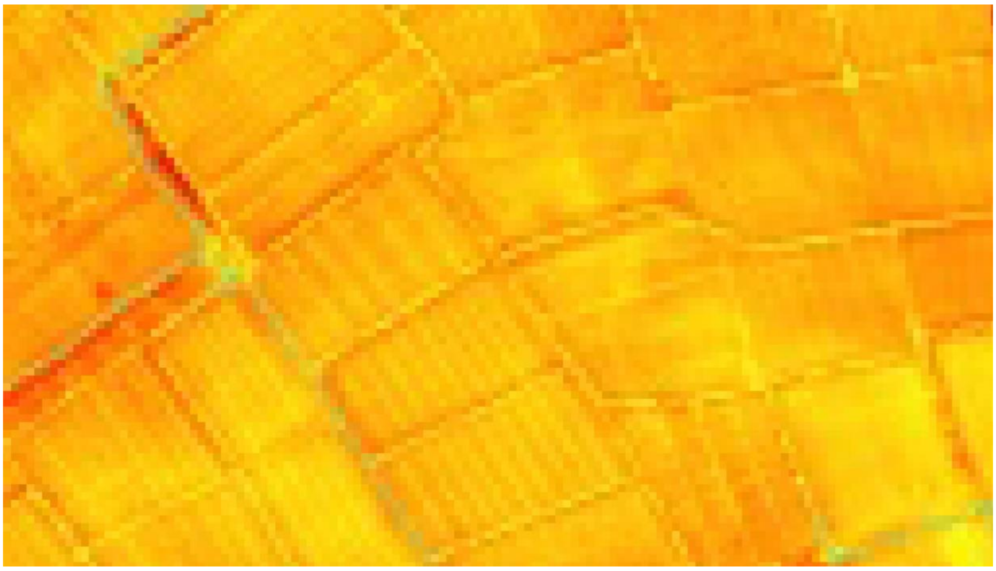


Figure 8: LIDAR image showing raised (red) field margins

Mole drains drawn into fields from ditch banks can be used to the same effect in primary or secondary furrows or in flat (dished) fields, provided sufficient freeboard is available. The impact of mole drainage on the soil water table can clearly be seen at tab A in Table 6.3-2 of the Rigare report, a time-series of soil water levels for Cross Farm (Chapel Road) shows the soil water table being held at 400mm below ground level through the wet, winter months.

Subsoiling and mole draining can offer a short (often one season in the case of subsoiling) and medium term (up to seven years in the case of mole drains) solution but, if carried out insensitively, can damage relict drains that are often too shallow to be able to discharge into the reens. Once a piped drainage system has been damaged it is expensive to repair and localised waterlogging of land can cause significant management problems.

Subsoiling lifts and fractures overlying soil by dragging multiple winged tines between 300mm and 450mm below the soil surface creating drainage pathways in the top- and upper sub-soil. Subsoiling relieves compacted layers and provides limited opportunity for effective lateral flow, often lasting for a single cropping year.

Where piped drainage systems have spacings of more than 10m and are gravel filled, the associated mole drains, which transfer water from the areas between pipes, should be renewed once in about five years. It is understood that some farms with piped drainage systems have failed to renew mole drains and consequently the drainage has limited efficacy.

Large fields where grips, ditches and reen systems have either been filled in or piped to make bigger fields, are a particular issue because it can be impossible to achieve adequate fall in mole or piped systems for effective working. Whilst piped drains can work at a level grade, expensive precision equipment is required to install systems accurately, but systems installed with as little as 400mm of cover, which is often necessary on large fields with little elevation, can be vulnerable to distortion associated with trafficking causing the system to fail. When the profile of a drain is distorted by soil movement and dips are created in a run, standing water at low points causes sediment to drop out of flow or prevents scouring of the bottom of the drain causing it to silt up and fail. In a mole drain, waterlogging causes structural failure of the soil around the 'pipe' accelerating the collapse of channels and causing them fail. Thus, in order for investment in drainage to be worthwhile it is imperative that soil water conditions in the soil profile are monitored, and trafficking avoided during wet periods when damage to drainage systems is inevitable.

Sustainable drainage

Sustainable land drainage systems and measures offer opportunities to realise the benefits of drainage systems by adopting a systems-based approach to increase nitrogen-use efficiency, while maintaining or increasing crop production, so that farmers and the environment can both benefit without any negative impact on social and cultural wellbeing.

In recent years, drainage systems have increasingly been designed to take into account crop production and water quality, moving away from removing water from the system as rapidly as possible towards controlling water in individual fields, providing opportunities for nitrate uptake and even reducing nitrates in drainage by filtration. Whilst these techniques were developed to reduce nitrate losses, they also bring benefits in terms of controlling soil and phosphorus loss and water supply, which are likely to be adversely impacted by climate change.

Control of water levels to modify soil water depth and duration of saturation is be facilitated by stopping and starting flow using valves or by adjusting drain depth and spacing. With valves, flow can be controlled to reduce the soil water table to below say 500mm in spring and autumn to allow access and hold back drainage to conserve soil water or flood piped drainage in the summer to provide water. This technique is already practiced to some extent in the Gwent Levels with the use of boards to control water levels over relatively large areas, but not on a field-by-field basis.

The relatively poor lateral permeability of the soils in the area means that the maintenance of summer high water levels in ditches is of limited value in terms of water supply to growing crops in large fields. This is confirmed in Figures 6.2-1 to 6.6-2 in the Rigare report, which clearly show evidence of a soil water table between 1.2m and 1.5m below ground level in fields with perimeter ditches with high retained summer water levels.

Shallow drains at relatively close spacings have also been shown to reduce the load of nitrogen leached through drainage systems[18]. Whilst losses are still likely to occur at a lower rate with lateral movement through the soil, the reduction in total loss will result in a lesser impact on surface waters. This technique is also to some extent practiced in the Levels with the use of mole drains, which, in the absence of excessive inputs from rainfall can maintain a soil water table at between 400mm and 500mm below the soil surface.

Critical to the success of any sustainable drainage system is the implementation of and integration with comprehensive nutrient management and crop planning that ensures that the correct amounts of nutrients are available to growing crops and that soil water conditions are right for plant growth.

Bioreactors and Wetlands

'End of pipe' techniques to reduce nitrate loss by providing opportunities for the denitrification of NO_3 to N_2, for instance by filtering drainage water through reduced carbon substrates such as woodchips contained in simple structures on field headlands or a constructed wetland. Few bioreactors have been installed in the UK although nitrate concentrations have been observed to be reduced by between 33% to 100% of concentration or 12% to 98% of load[19].

Bioreactors are an integral part of an underground drainage system excavated to the same level as the pipe invert and the void lined with geo-textile and filled with wood chip. A bioreactor measuring 4m x 25m x 2m deep costs in the region of £2,500 to install and would serve about 20 acres of land in the UK. Control structures are installed at both ends of the reactor to regulate the flow of water passing through and thus the retention time in the treatment area chamber. The life span of bioreactors in UK is unknown but in the USA, where a number have been installed for up to ten years, it is anticipated that they will have a life of between 20 and 25 years.

[18] Long-term impacts of drain spacing, crop management, and weather on nitrate leaching to subsurface drains. Kladivko j. & Bowling L. C., Journal of Environmental Quality. March 2021

[19] A PRACTICE-ORIENTED REVIEW OF WOODCHIP BIOREACTORS FOR SUBSURFACE AGRICULTURAL DRAINAGE L. E. Christianson, A. Bhandari, M. J. Helmers (2012) Iowa State University Agriculture and Biosystems Engineering. Vol28(6):861-874 (2012)

Constructed wetlands (reedbeds) are commonly used to polish final effluent from small scale sewage treatment plants before it is discharged to surface waters. Reduction in nitrogen loadings can be as much as 50% in mature wetlands and they have an expected lifetime of more than 25 years with minimal maintenance. The cost of a constructed wetland to serve 20 acres would be in the region of £3,000 - £5,000 which will vary according to the need for and cost of a soil matrix. Constructed wetlands carry out an attenuation role that should be fulfilled by a properly functioning wet ditch system, whilst providing wetland habitat.

Buffers

Buffers along wetland ditch margins reduce nitrogen losses by providing opportunities for increased plant uptake and denitrification of water flowing across or through the topsoil. Buffers normally fall from the cropped area of a field to the ditch top but in the Levels ditch margins are often raised a few centimetres where arisings from ditch cleaning have not been spread widely in the field, so obstructing run off. Further, long narrow fields are not suited to the installation of buffer strips because they occupy a disproportionate area of the field. Buffer strips are however well-suited to arable fields and heavily-modified grassland in areas with a low density of boundary ditches.

In parts of the Levels with long, narrow fields it would be more appropriate to convert grassland based on ryegrass leys to clover or herbal leys. Any move away from ryegrass leys would reduce the amount of nitrogen fertiliser used on grassland and so reduce the risk of nitrogen pollution.

Appendix 3 – Drainage Impacts

It is clear that drainage can have a significant impact on productivity, nutrient uptake, access and workability of land, as well as potential increases of pollution of surface waters by nutrients and agrochemicals and damage to soils. In order to assess the benefits and risks likely to come with drainage it is necessary to quantify elements of improvements in financial terms in order that they can be assessed against the cost of those improvements and the risks attached to failure.

Likely financial impacts of change in terms of benefits and costs are set out Appendix 1.

Generally, the benefits of drainage are related to increased access and a longer growing period that improves the range of crops that can be grown and productivity where it is not limited by climate. Specific benefits of drainage include:

- increased organic matter storage through increasing rooting depth[20];
- improved germination, yield and quality of crops;
- faster warming of soils, improved environment for soil organisms, better plant root access to water and oxygen and better fertiliser uptake;
- less waterlogging of soil and reduced damage to crops or grazing land;
- better land access to land due to reduced waterlogging allowing better timing of crop inputs, including fertiliser and pesticides;
- improved work rates and fuel use through fewer cultivation passes, fewer wet areas to avoid, reduced wear and tear, and better traction;
- reduced poaching by livestock;
- reduced surface run-off and consequent loss of soil, phosphorus and pesticides;
- better livestock health with lower worm burden; and
- reduced risk of soil contamination during forage harvest.

Many of these benefits are directly related to the ability of farmers and land managers to implement management measures to improve or diversify production and equally most of the risks associated with land drainage are associated with poor management of drained land.

[20] https://www.nature.com/articles/srep45635
https://www.nfm.scot/sites/www.nfm.scot/files/CRW2014_03%20Final%20report_0.pdf

Conversely, there are risks, or drawbacks associated with drainage, although these are negligible on terms of most farm businesses. Undrained land can offer ecosystem services in terms of flood compensation or habitat provision, but little to enhance natural capital valuation when compared with provision of food.

Wet habitats are important for birds and other wildlife and drainage can degrade important wildlife habitats if not carried out sympathetically. Unlike the destruction of unimproved grassland, which requires EA under the Environmental Impact Assessment (Agriculture) (Wales) Regulations 2017, as amended. Outside of SSSIs there is no requirement for the environmental assessment of agricultural land drainage schemes where the land is already improved.

Although peatland is extremely uncommon in the area, the disturbance and draining of peat is likely to accelerate its decomposition and so increase greenhouse gas emissions. The disturbance of peat below layers of heavy clay, for instance by over-deepening a reen, can result in subsidence where peat is displaced into the over-dug ditch. This results in the ditch being blocked and often the sides of the ditch collapse into the space vacated by the displaced peat.

Poor drainage increases the risk of loss of fertiliser, and organic manures, applied to growing crops, as the input is not fully taken up by the crop because of waterlogging. This can in turn be reflected in increased leaching of nitrogen and loss of phosphorus in run off, both of which have an adverse impact on water quality.

Some improved land is used for relatively low intensity agriculture and so may be wet or occasionally wet for extended periods and can be important for foraging wildlife. Land or parts of fields where the drains or ditches have fallen into disrepair may now be wet beneficial for wildlife. Often a farm will have a wet or often flooded area which is less productive but is also used more by farm wildlife. Draining any of the areas described above to improve productivity is likely to negatively affect wildlife in some way.

Over time drainage systems need to be maintained, replaced or reinstalled. Ditches become silted or blocked, mole drains collapse and field drains become inefficient. Rainfall at both ends of the farming season restricts farming operations in areas with deteriorating drainage and often results in either loss of crop or damage to soils. Poorly maintained systems, whilst they can provide habitat can pose a risk to farm business viability and water quality alike.

Appendix 4 – Justification

Underground land drainage is an expensive capital investment costing between £2,000 and £4,500 per hectare and having an economic lifetime of between 30 and 50 years. It has to compete with other investments for money that might be available for capital projects in a business, thus it has to be justified carefully in terms of the benefits it can reliably provide. Some drainage operations, like mole drainage and gripping are less expensive to install and maintain at an interval of between three and seven years and thus might be seen as routine farming operations, so they are not considered capital expenditure.

Not all farmers regard regular drainage as essential to a sustainable business, many see it as an expensive outlay of doubtful value compared with other projects in their business. It is these latter businesses that may have neglected underground and often surface drainage systems to the detriment of in field drainage. Before seeking to justify underground land drainage those considering drainage should first ensure that the existing system is functioning, and ditch cross sections and depth are appropriate for an effective system.

Justification is further complicated by the life of drainage systems set out above, which means that we are in a period when drainage schemes installed between 1960 and 1980, when grants were last available for drainage, are coming to the end of their useful life. This increases the likelihood that replacement schemes will be necessary in the near future.

In some situations, even where the cost of installation would be justified, it is simply not possible to install a drainage system, due to the amount of available freeboard as described above. Further any underground system with mole drains in the Gwent Levels has to be based on lateral drain spacing of 30m with gravel cover above to within 300mm of the soil surface. To work across a whole field, the gravel overlaying the piped system has to be intersected by mole drains spaced at between three and five metres at a depth of about 400mm below the soil surface. A system to this specification requires a minimum freeboard between the lowest part of the field and the maximum water level in surrounding ditches.

Arable

Given the recent history of arable agriculture in the United Kingdom, particularly the availability of generous grants for the post-WW2 improvement and installation of drainage systems, it is very likely that a significant proportion of arable land in the south of the Levels has been drained intensively at some time in the past 60 years. It is critical to farming businesses and production generally, that existing drainage systems for arable agriculture are maintained and replaced as necessary to maintain productivity and avoid reversion to low grade land, suited only to grassland farming. This may already be happening in some parts of the Levels and abandonment is likely to have a moderate to severe impact on businesses and thus land management in the area.

Well designed and managed systems together with good husbandry avoid pollution and maintain good yields and so should justify investment in their own right in most arable operations. In many businesses, planned investment in capital funded infrastructure might be funded from a sinking fund to which funds are allocated on an annual basis. This practice is not common in farming and it is more likely that investment in any replacement system will be funded from borrowings or profits, where available.

The benefits on arable land from land drainage will vary from year-to-year and between farms according to climate, soil condition and husbandry. In order to facilitate valid comparisons, the analysis of performance uses standard values for costs and outputs.

Dairy

Land used for dairying is less likely to have been improved with agricultural land drainage because many dairy farms has changed significantly over the past fifty years as a result of pressures around input costs, milk prices and quotas. In the Gwent Levels, dairy herd sizes reflect the reaction of farm businesses to those pressures and the area has seen a polarisation of farm types, from relatively small extensively grazed family farms to much larger intensive units with mainly housed herds relying on conserved forage.

Again, the benefits from drainage will vary between years and according to the scale of the operation. A grazing herd will be able to take advantage of an extended grazing season, whereas a housed herd will have access to more, better quality home-produced forage.

Beef

The benefits for drainage-driven improvement in beef farming are similar to those in dairying but the returns are slightly lower. The benefits will vary less between units which operate broadly similar extensive productions systems in the area.

Sheep

Sheep farming is less common than other livestock husbandry being limited to fields with boundaries that can contain animals safely.

Sheep are often farmed with other livestock to take advantage of good summer grass production in the area, so benefits accruing to businesses from sheep production are secondary to a principal farming activity, such as beef or arable production. Any specific improvement in farm income from sheep production accruing from drainage is likely be a small part of overall improvement and it is unlikely that a landowner would rely on income from sheep to fund drainage works.

Diversification

Diversity is at the very heart of many aspects of the Levels, and the landscape supports a number of different types of farm and land based businesses.

- dairying
- arable
- beef
- sheep
- orchards
- eco-tourism

These sectors in turn can support land-based businesses that may include specialist food production including yoghurt, cheese, apple juices, cider and added value products from locally sourced beef and sheep; specialist forage for the domestic and leisure animal sectors. All of these forms of diversification can support farm businesses and facilitate investment in drainage which is critical for production in the area.

Drainage manifests itself in the landscape through open water and the reen and ditch network with its hedge lines and standard trees. The surface drainage network underpins the SSSIs that span the area and also ensures that farmland is accessible and productive by removing surface water by way of ridge and furrow features and associated grips, with piped and mole drains helping maintain access in the wake of summer rainfall and for longer at the beginning and end of the growing season.

Whilst the soils of the Levels are remarkably consistent and the topography seemingly flat, the relative elevations of areas influence land use. Higher land to the south of the area can be and frequently has been intensively drained and so is well suited to arable farming, lower lying land in the north and central areas is not so elevated and thus is less well suited to land drainage.

Appendix 5 – Future Drainage

This section addresses both underground land drainage and traditional surface drainage systems in the Gwent Levels. In addition to drainage operations on and under fields, it is also necessary to take into account the costs of maintaining riparian ditches on field perimeters, which have been included in the analysis at Appendix 1.

Drainage plays an important role in the future of the Gwent Levels, underpinning the landscape in its historical and present day delivery of places to live and work, sustenance and general wellbeing. Options for the future of the Levels have to take into account the policy and regulatory environment, including the Well-being of Future Generations Act and the Environment Act, as described in a recent written statement from the Welsh Government's Minister for Climate Change[21].

Any future farming systems in the Levels have to respect and enhance the traditional drainage network and the biodiversity it supports as well as the historical features that have led to their designation as a Landscape of Outstanding Historic Interest in Wales. The Levels' location, adjacent to two major population centres in Wales, means that they also face pressures from recreational use although visitors can also bring benefits, providing opportunities for the diversification of businesses, and the direct marketing of specialist products of local provenance, as identified by the Sustaining the Gwent Levels project and the Living Levels programme.

So, to secure a future for the area, farming needs to diversify, improve and intensify in sustainable ways[22] in order to provide incomes for farming families, work for local people and guarantee the future of the Levels as a unique and valuable entity in South Wales. Drainage forms a critical element of that future, it enables or restricts farming practices, supports the biodiversity of the area, and is at the core of the Living Landscape and what the area delivers to locals and visitors alike.

The Welsh Government envisages that land management agreements will be a key tool to enable farmers and land managers to carry out important work that will support all aspects of the anthropocentric ecosystem that makes up the area. This role of farmers and land managers

[21] https://gov.wales/written-statement-taking-action-better-protect-and-manage-gwent-levels

[22] Sustainable intensification in agriculture involves increasing or diversifying output without having adverse impacts on the environment or using more land.

in the Levels is not new, it has been in place for more than two millennia, and the future of the area relies on it continuing.

The research and investigations underpinning this and other reports associated with the Sustaining the Gwent Levels project have highlighted the unique, highly evolved and interdependent nature of the drainage network, its causal role in the use of land for different sorts agriculture and thus the built and natural landscape of the area. No system stands still and the post WW1 development of land drains with immediate post WW2 intensification has seen the establishment of conditions that have supported the natural and man-made features that make the Levels what they are today. Recently however, external pressures such as changing markets, increasing population and a changing environment have driven major change.

The construction of Llanwern steelworks, which opened in 1962, consumed nearly 500ha (1,200 acres) of grassland and wetlands that supported similar habitats to those we see today in some parts of the Levels; that is almost 10% of the area of the Levels' SSSIs. More recently, the development of large scale photovoltaic solar 'farms' have seen the demise of low value agricultural wetlands for at least 25 years with no certainty regarding how that land and associated drains are managed.

Future farming systems have to have capacity to support the Welsh Government's vision for the Levels whilst sustaining farm businesses and the families they support. Large scale farming systems are not necessarily well suited to the area. Intensive cropping requires flexibility of land use, often making use of large machines that the soils of the area can't reliably support and suffering short access periods on low grade agricultural land that has severe limitations. Major changes to cropping will require significant investment for relatively marginal improvement, which is extremely likely to be unsustainable. Farming success is likely to be driven, not by intensification of existing husbandry systems but by diversification and adaption to realise outputs that will support the farming community and what it needs to do to support a Living Landscape.

Appendix 6 – Stakeholder Engagement

In the course of preparing this report, a series of conversations were held with a number of farmers and others involved in land-based activities within the study area. In order to encourage frank inputs to the exchanges, none of the comments below have been attributed to individual contributors who, for the purposes of this exercise, remain anonymous. This section summarises how farmers view their heritage and the Levels today, describing features in the drainage system where relevant.

Field observations by RAC, carried out in response to farmer comments, suggest that two problems that have precipitated these issues

- lack of resources within parts of the farming community has resulted in the neglect of maintenance of the ditches existing drains in some areas resulting in slowing down of flows across relatively large areas;
- lack of understanding of the drainage system on the part of new riparian owners as resulted in similar neglect.

Both these points have also been identified by the work done with farmers in the Living Levels Programme.

Both problems, particularly regarding the responsibilities that accompany riparian ownership, would benefit from more effective stakeholder engagement. Engagement with the full range of stakeholders would also highlight the problems caused by lack of maintenance and the full range of reasons underlying it. Only in full knowledge of the latter can decisions be made on the direction of funding designed to restore the surface drainage system to good condition.

Agricultural land drainage to maintain and improve the sustainability of farming businesses in the Levels is evidently desirable in some areas but cannot proceed until the surface drainage system in areas requiring improvement has been fully restored. Only after surface drainage has been restored and the impacts on fields assessed, can the feasibility of land drainage, be it piped or mole drainage, be considered.

It is anticipated that with understanding of the system will come acceptance by some stakeholders that intensive drainage is not feasible across the area and the limits applying to land parcels will be used to promote sustainable, nature-friendly farming and diversification into low intensity agriculture and the growing of crops better suited to the local environment.

It is important that changes in husbandry and land management do not have adverse impacts on the natural ecosystems of the Gwent Levels or services including flood regulation, water quality regulation, climate regulation and culturally specific services.