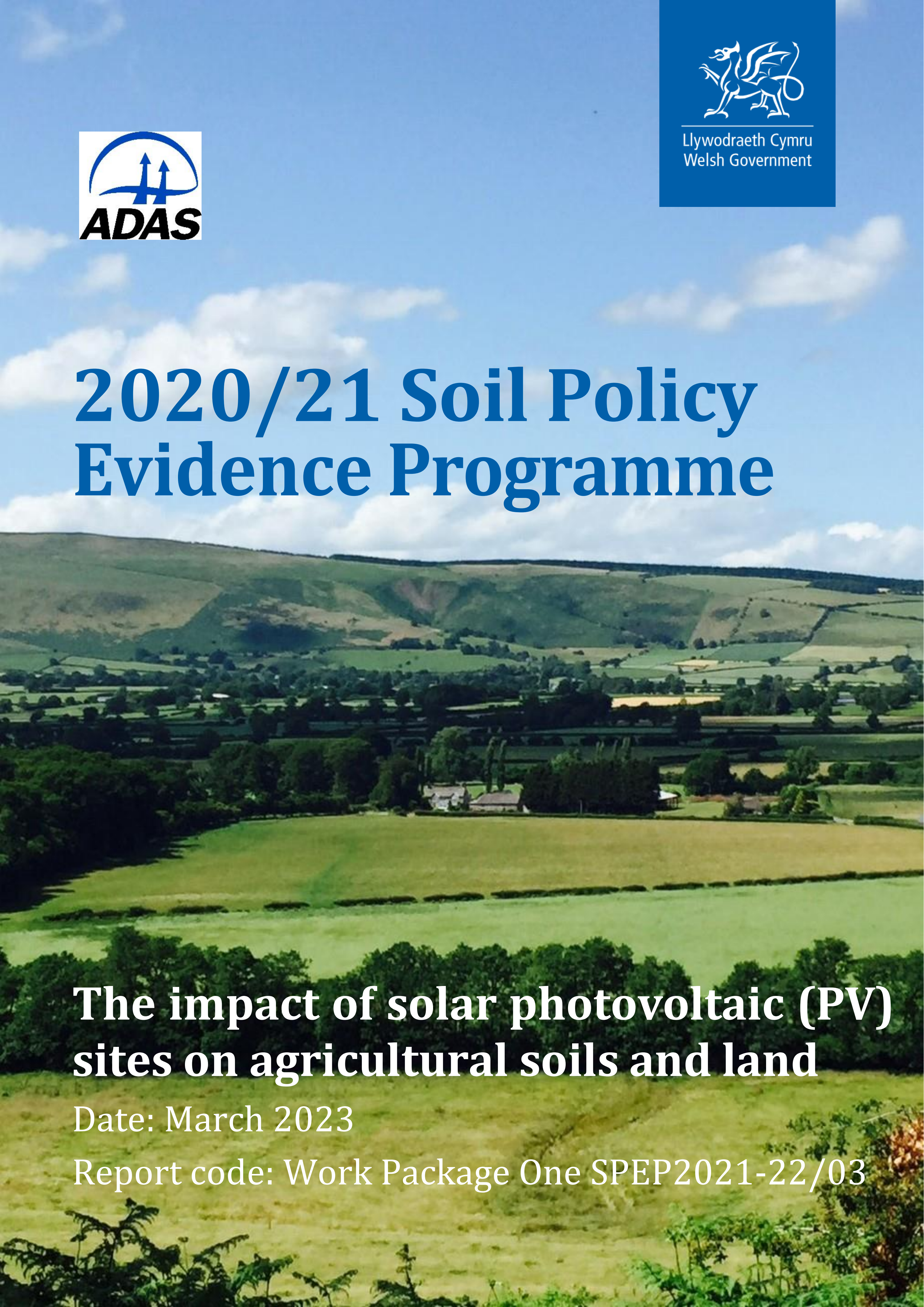

Llywodraeth Cymru
Welsh Government

ADAS

2020/21 Soil Policy Evidence Programme

The impact of solar photovoltaic (PV) sites on agricultural soils and land

Date: March 2023

Report code: Work Package One SPEP2021-22/03

Welsh Government

The impact of solar photovoltaic (PV) sites on agricultural soils and land

Work Package One: Literature Review

March 2023

ADAS

ADAS GENERAL NOTES

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EXECUTIVE SUMMARY

This report provides a literature review of the impact of solar photovoltaic (PV) sites on Best and Most Versatile (BMV) agricultural land (MAFF Agricultural Land Classification Grade 1, 2 and 3a land) and associated soils. The aim is to inform Welsh Government and Natural England specialists when dealing with solar PV planning applications.

The scope covers a review of relevant research and industry experiences related to the impacts of solar PV sites on agricultural land and soil, within the UK and internationally. Also reviewed are the impacts of other temporary developments activities such as minerals, golf courses and gas pipelines.

There have been few studies of solar PV sites which have a focus on the impacts on agricultural land and soils. This is largely because solar PV sites are recent developments but also because in the early years sites were located on brownfield land or poorer quality agricultural land. The potential to achieve successful restoration of solar PV sites has increased in significance as the number, size and operational timeframe of solar PV sites on BMV agricultural land has increased.

There are several in-field research studies that consider the net environmental gain of solar PV sites. The longer-term impacts of solar PV infrastructure on agricultural land and soils and the recovery time post-decommissioning have been identified by this literature review as areas requiring further study.

CONTENTS

1 BACKGROUND

This report is part of an evidence-based assessment of the impact of solar photovoltaic (PV) sites on Best and Most Versatile (BMV) agricultural land[1] [2] and associated soils. The work, under the Welsh Government's Soil Policy Evidence Programme SPEP 2021-22/03, is to inform Welsh Government and Natural England specialists when dealing with solar PV planning applications.

Current Welsh Government policy[3] states that '*planning authorities should bear in mind that, once land is built on, the restoration of semi natural and natural habitats and landscape features is rarely possible and usually expensive, and archaeological and historic features cannot be replaced. Also, once agricultural land is developed, even for 'soft' uses such as golf courses, its return to agriculture as best and most versatile agricultural land is seldom practicable.*'

A detailed search of published research and industry experience has been undertaken to inform this report. The search concentrated on the impacts of solar PV sites on agricultural land and soils within the UK and internationally. Key words and phrases used include '*impact of solar PV sites on land and soil*', '*installation and decommissioning*', '*reversibility of golf courses*', '*orchard grubbing*', '*glasshouse structure and demolition*', '*pipeline restoration*' and '*mineral site restoration*'. Feedback references from a virtual workshop held on 2nd September 2021 with Welsh Government, Natural England and invited interested parties have been followed up.

Research has been undertaken in the UK on the impact of solar PV sites on ecosystems. The Solar Parks Impact on Ecosystem Services (SPIES) is a decision support tool (Randle-Boggis et al, 2020) which is aimed at both the development and operation of solar PV sites. A field-based study undertaken by Armstrong et al (2016) considered the microclimate for 12 months on plots under solar PV arrays. The study identified seasonal and diurnal variations in air and soil microclimate, and a vegetation response to the microclimate and management activities. The microclimate explained the difference in above ground plant biomass and

[1] Planning Policy Wales Paragraphs 3.58-3.59 Edition 11 February 2021 and National Planning Policy Framework

[2] Land classified as Grade 1, 2 and 3a. MAFF Agricultural Land Classification Guidelines. 1988

[3] Welsh TAN 6 (Technical Advice Note 6, Planning for Sustainable Rural Communities (2010))

species diversity, which were both lower under the solar PV arrays. The next stage of this work was to use this evidence to optimise solar PV site design and management for delivery of ecosystem services.

Land use change, often from an arable use on BMV agricultural land to low-maintenance grassland, has been cited by developers in planning applications as a benefit arising from solar PV sites. This may appear to be a realistic proposition but it is not currently supported by long-term studies specifically relating to solar PV sites.

In the absence of specific long-term studies planning applications often make statements on the benefits of land '*reversion*' – moving from intensive agricultural use to low-maintenance grass beneath solar PV arrays.

Reports of changes in soil health resulting from land reversion are reported by Conant et al (2001). Increased soil carbon storage is reported by Defra (2009), with the actual value of soil carbon storage depending on soil type, previous land use and climate. After an initial increase, estimated to occur for up to 20 years, it was reported that carbon storage rates slow and cease when a new equilibrium is reached at some point between 50-100 years.

Defra (2009) also reported that changes in tillage practice, such as reduced or zero tillage systems, would reduce soil organic matter oxidation and benefit soil organic matter. The introduction of rotational grass for 2 or more years would benefit soil organic levels. A study (Fullen et al,2006) on grass-ley set aside reported increases in soil organic matter. There are a limited number of research studies, which refer to soil carbon on solar PV sites (Choi et al, 2020). While the impacts of solar PV sites on biodiversity have been reported, evidence to support the reversibility and longer-term impact of installation, operation and decommissioning on agricultural land and soils is open for discussion.

2 WORKSHOP

This review aims to encompass a broad range of experience and evidence. A virtual workshop, hosted via MS Teams, was organised for 2nd September 2021. For representation by the solar industry ADAS approached Solar Energy UK, a trade association with over 230 member companies; Lancaster University, authors of the SPIES tool for assessing solar proposals; and the Department for Business, Energy and Industrial Strategy, BEIS. Also invited were agricultural land and soils experts from Welsh Government, Natural England and third parties.

The workshop largely ended up as a round table discussion. There were few specific outcomes to the workshop but it was useful to this review to hear a broad spectrum of voices. Rob Askew, of Askew Land and Soil, approached Solar Energy UK to provide agricultural land and soils input into a forthcoming industry guidance document. A good number of solar related references, papers and industry experience were exchanged. These led to new avenues of enquiry which have been included in this literature review and will inform later work. ADAS thanks all parties for their valuable input.

2.1 Attendees

Role	Organisation	Name	Specialism
Chair	ADAS	Richard Sowden	Solar
Organiser	ADAS	Martin Worsley	Soils
Welsh Government	Welsh Government	Ian Rugg Arwel Williams	Soils Soils
Natural England	Natural England	Julie Holloway	Soils
ADAS Soils	ADAS	Ruth Metcalfe	Soils
External Soils	Askew Land & Soil	Rob Askew	Soils
Solar Specialist	BEIS	Edward Mason Boris Rogatchevski	Solar Solar
Solar Developer	Next Energy Capital	Sulwen Vaughan	Solar
Solar Developer	Eden Renewables	Harry Lopes	Solar
Solar Ecologist	Clarkson & Woods	Belinda Howell Tom Clarkson	Ecology Ecology

2.2 Agenda

1) Introductions
2) Purpose of workshop - Richard Sowden, ADAS
3) Context of research project – Ian Rugg, Welsh Government
4) Initial research findings - Ruth Metcalfe, ADAS
5) Solar developers' input - Sulwen Vaughan, Next Energy Capital
6) BEIS input – Edward Mason, BEIS
7) Ongoing research – Belinda Howell, Clarkson Wood
8) Roundtable discussion of key questions:
    a. What benefits do solar PV sites offer to agricultural soils and land?
    b. How do soils interact with the wider ecological benefits of solar PV sites?
    c. What risks do solar PV sites pose to agricultural soils and land? And what is an acceptable risk level to tolerate?
    d. What mechanisms or barriers are there to reducing risks during the installation, operation and decommissioning?
    e. What conditions should be met for at a successfully restored site? Does this differ for higher quality agricultural land compared to poorer quality agricultural land?
    f. How realistic is the claim that solar PV sites on greenfield sites are a 'reversible' loss of agricultural land? Is solar being used as a precursor to permanent development down the line? Or successive solar developments?
    g. How long should planning permission be granted for? Technology changes so how many sites will be operational in 40 years time? Risk of derelict sites.
9) Wrap up.

3 LITERATURE REVIEW

This report reviews published research and industry experience related to the impacts of solar PV sites on agricultural land and soils, within the UK and internationally. Also reviewed are the impacts on agricultural land and soils of other temporary uses, within the UK and internationally.

3.1 Research

Many investigations into the environmental impacts of solar PV sites use a life cycle assessment (LCA) framework (Turney and Fthenakis, 2011), which has a focus on greenhouse gas emissions and energy payback time. A comparison of the recovery time of land is made between mining activity and solar PV sites. It is suggested that recovery after solar PV sites is likely to occur more quickly but such a hypothesis requires further research.

The recovery time of agricultural land and soils following disturbance can be years to many decades – and is dependent on many factors, including climate. A research project (Defra,2016) identified compaction in grassland as an issue in the context of agri-environment scheme objectives in England and Wales. The most compacted soils were found to have a reduction in yield potential, habitat support and soil biodiversity. The recovery time of agricultural land and soils will be specifically addressed in WP3 of this work programme.

Choi et al. (2020) recognised that utility scale solar PV sites are land intensive and can have negative impacts, such as '*extensive landscape modifications that transform soil ecological functions, thereby impacting hydrologic, vegetative and carbon dynamics*'. An investigation of critical soil physical and chemical parameters at a revegetated solar PV site and an adjacent reference grassland in Colorado USA was undertaken. After 7 years the investigation found a greater fraction of coarse particles in the solar PV site soil than in the reference soil and considered that the difference arose during the construction phase. This is attributed to the disturbance of topsoil, the addition of fill and the removal of native vegetation, which can accelerate erosion of fine soil particles. Infiltration rates were recorded as part of the study and results were similar between the solar PV site and the reference site. However, a discrepancy was identified between expected and observed hydraulic conductivity below the solar PV panels. The higher infiltration rate below the panel may be attributable to the reduced exposure to site maintenance activities that cause compaction.

The Solar Parks Impact on Ecosystem Services (SPIES) decision support tool (Randle-Boggis et al, 2020) is aimed at the development phase and operation of solar PV sites. The key emphasis is on natural capital and the ecosystem service benefits from solar PV sites. Randle-Boggis et al acknowledge that while the benefits to ecosystem services and natural capital are recognised, the longer-term impacts of solar PV sites on ecosystems have to be resolved. They qualify their work by stating that the '*potential environmental effects and ecological responses have been summarised*' but '*only a limited number of impacts have been quantified at individual sites*'.

Tercan et al (2021) present a framework for spatial planning of solar PV sites using GIS tools and a multi-criteria assessment approach at a regional level in Turkey. Land use/cover is used as one layer although there is no direct reference to soil types or agricultural land quality. A study (Palmer et al, 2019) used GIS tools to consider site suitability in the UK and concluded that network connections and slope should be considered in any analysis. The study referred to publicly available Agricultural Land Classification maps in England [4] and reported that 16% of solar farms were located on agricultural land classified (ALC) as Grades 1 and 2. The report noted that '*there is the additional difficulty that available maps do not stipulate whether Grade 3 land is 3a or 3b*.'

A method has been designed within an Integrated Assessment Model (IAM) which links energy, land, socioeconomic and climate systems to consider the potential land requirements for solar PV sites in Europe, India, Japan and South Korea (van de Ven, DJ., Capellan-Peréz, I., Arto, I. et al.,2021). The study reports that by 2050 with a 25%-80% penetration of solar PV in the electricity mix, solar energy may occupy between 0.5% to 5% of total land. The impact on terrestrial carbon stocks is also considered.

3.2 Experience

BRE (2013) gives planning guidance on solar PV sites. There is reference to the assessment of the impact on agricultural land using the MAFF Agricultural Land Classification system. A section on soil stripping, storage and replacement is included with advice that a methodology on these should form part of the planning application.

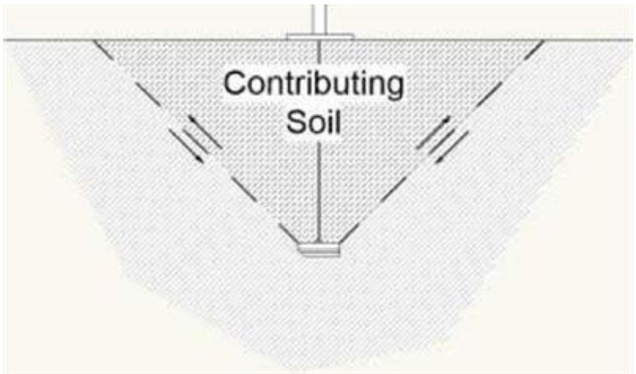
[4] In England the publicly available Agricultural Land Classification maps (scale 1:250 000) are for strategic use and are derived from the Provisional 1 inch to 1 mile Agricultural Land Classification maps published between 1967 and 1974. The maps show Grades 1 to 5, but Grade 3 is not subdivided. In Wales the Predictive Agricultural Land Classification Map (Welsh Government, 2021) shows the subdivision of Grade 3 (3a and 3b).

BRE (2014) sets out guidance for good management practice of small livestock on solar PV sites. There is brief reference to best practice during the construction phase, including the need to avoid soil compaction. Storage of topsoil and subsoil separately and the replacement of topsoil and subsoil are also briefly mentioned in order to avoid long-term visible negative impacts on vegetation and the underlying soil structure. No reference of restoration to previous agricultural land quality is made.

BRE (2014a) gives guidance on biodiversity for solar PV sites and the need for a biodiversity management plan. The guidance covers the reversion of land use at the end of a solar PV site's life and that habitat enhancement planning should take this into account. There is reference to Good Agricultural and Environmental Condition and the role of stewardship of the land for the lifetime of the solar PV site from design to the end of life of the solar PV site.

Several planning authorities have prepared their own guidance on solar PV sites (Kent County Council, 2014; Maidstone Borough Council, 2014). North Somerset Council's Supplementary Planning Document (North Somerset Council, 2013) states that solar PV sites on agricultural land must be '*reversible*' allowing the site to be easily restored to agriculture. Intrusive groundworks, such as trenching and foundations, should be minimised and the use of concrete avoided where possible. Frames should be pile driven or screw anchored and not concrete-based, and capable of easy removal, allowing the ground to be fully restored. There is little detail on how this could or should be delivered. North Somerset Council state that an Environmental Statement should assess the impact of the development on soil. The environmental statement is to consider short, medium and long term effects and whether they are temporary or permanent. No specific detail is given for soils.

A variety of ground anchors can be used on solar PV sites, as shown in a press release on the structural overview of ground anchors prepared by an American commercial manufacturer of ground mounted solar racking systems. An '*earth anchor*' driven to about 1m below the ground surface '*engages*' with a cone of soil above it with a volume of about 0.8 m^3 (Nuance Energy, 2017). Ludt (2020) presents an article on the typical ground supports used for different soil types. I-beams are widely used on a variety of soils, while helical piles are suitable for areas with high water tables.



Soil cone- Nuance Energy (2017)

In the UK some solar PV sites give an outline of site decommissioning with detail to be provided nearer the site's end of life. The Decommissioning Statement prepared for Overton Solar Farm, Hampshire (Belectric, 2014) described the operation as a simple process and referred to backfilling. Solar Partners XI (2019) prepared a decommissioning plan for its Gemini Solar Project to the north east of Las Vegas. The plan was to be reviewed 5 years before the planned closure and a Final Closure plan prepared. The site was ecologically sensitive and a baseline survey included soil information to be used for planning the backfilling of voids, reference to the evaluation of soil decompaction and a site restoration plan. Annual monitoring after closure would be undertaken for at least 5 years.

Ludt (2019) commented in the American trade press that de-commissioning was a current issue which would become significant in the next couple of decades. Decommissioning is described as a solar PV site doing an installation in reverse with structural holes filled where the arrays have been mounted. The aim is to leave the site as if it has never had a solar PV installation.

The Solar Trade Association (2019) gives a figure of 5% as typical of the ground disturbance within a site. The Association's Land Management Charter refers to returning the solar site to its former use.

Solarpower Europe (2020), is a member-led association representing organisations involved in solar power. The association has considered best practice and refers to soil properties influencing the severity and rate of corrosion of the racking material. The process of corrosion and interaction of the supports with the soil is presented in an article by the American solar trade (Blue Oak Energy, 2015). Ideally the pile should be driven into a compacted soil to minimise contact with air and water, but in reality this does not occur.

3.3 'Softer' developments e.g. golf courses, glasshouses, orchards

There are very limited documented experiences of the impacts of other uses such as golf courses on agricultural land and soil within and beyond the UK. No reports of impacts from either glasshouse removal or orchard grubbing have been found, this includes conversations with ADAS specialists in these areas.

A study (MAFF,1995) was undertaken to assess the impact of golf course development on BMV agricultural land and the reversibility of golf courses to an agricultural land use. The project found that while the impact of golf course development does vary significantly with golf course type, certain features can lead to the irreversible deterioration of agricultural land quality. The greatest irreversible loss of BMV agricultural land on golf courses is a result of earth shaping and sterilisation of land (undisturbed land that is made inaccessible). Much of the irreversible loss of BMV land was a result of inappropriate handling of soils, when carrying out earthshaping, resulting in severe compaction. The higher the number of features, particularly in designs of the American/Japanese style, the greater the amount of land that is damaged or sterilised. It was reported that fewer than half of the golf course designers understood agricultural land and the reversibility of golf course development. Whilst a general level of understanding of issues on reversibility was expressed by several designers the impact of a particular design and construction on agricultural land quality was not fully understood.

There are some experiences of golf courses returning to an agricultural land use but no detail on the quality of land attained. A planning application in Buckinghamshire (2016) intended to restore part of a golf course to agricultural land use with the importation of soil and recycled hardcore. There had been previous activity to restore other parts of the golf course to an agricultural land use and this activity found larger quantities of hardcore were used in the golf course construction than were proposed in 2016 for the restoration to agriculture. The application for planning permission was refused as the proposal failed to demonstrate that there would be a gain in agricultural benefit sufficient to outweigh the impact on the residential amenity.

Further examples found in regional press include the following:

- Taunton Vale Golf Club (Somerset County Gazette, 2016)
- West Chitlington Golf Club (The Argus, 2016).

A farming trade press article reports the marketing of a former golf course in Ireland (That's Farming, 2020) as '*being easily converted back to agricultural use*'. When the golf course was constructed in 1993 there was minimal disturbance and no underground irrigation system or other piping was installed.

The Environmental Statement (Land Use and Agriculture) (National Grid, 2014) prepared for the Yorkshire and Humber Cross Country Pipeline considered the potential impact on the quality of soils. Activities were identified that may lead to potential effects on the existing soil structure: topsoil stripping, excavation of trenches, storage of topsoil and subsoil, use of construction compounds, severance of field drains and the reinstatement of soils. Change to soil characteristics such as soil hydrology and soil structure could occur due to handling and storage of topsoil in inappropriate conditions. The result could lead to compaction, soil mixing, inverted soil profiles and poor drainage during the construction phase. The environmental statement considered the magnitude of the effect and the sensitivity of the receptor. The magnitude was small as the working methods followed the Code of Construction Practice and the soils were classed as having a high sensitivity. Using significance categories, the effects are temporary (soils ready for planting the following season) and are considered to be minor in the environmental statement.

Investigations at a number of sites following pipeline installation identified severe subsoil compaction (Batey, 2015) as the cause of poor crop growth or drainage. Remedial action included the installation of additional land drains, increasing the amount of gravel above the drains and further subsoil loosening. After appropriate remedial action the crop losses were reduced.

ADAS has for many decades had a team that specialises in temporary construction projects and their impacts on agricultural land and soils. ADAS (Kirk Hill, pers. commun., 2021) report that the circumstances described by Batey (2015) are commonplace and that this is not merely confined to sites with poor soil handling practices. Even when best practices are followed the inherent vulnerability of soils to damage and the unpredictability of rainfall patterns during or even after restoration can impact on the success of the restoration. However, proper pre-construction assessments, planning and good on-site practices will reduce the potential for long term and severe damage.

There are no research reports of the impacts from either glasshouse removal or orchard grubbing on agricultural land and soils. Experience within ADAS (2021a) shows that glasshouse removal includes the removal of building materials (concrete, steel, glass), pipes (plastic and steel) and fuel tanks. There are no reports of adverse effects on agricultural land and soils following removal. Experience within ADAS (2021b) has found that in the majority of cases grubbing of established orchards can be achieved by pulling (tractor with chain around main stem of tree) or pushing (using a JCB or similar soil excavator). A high proportion of the main root system of each tree is removed along with the branches and main stem with minimal disturbance to the soil around the trees. In traditional orchards, where the root system is deeper, as a result of competition with the grass sward, the soil disturbance produced by the removal of an individual tree is likely to be greater than in a close spaced row and rectangular planted orchard. After grubbing the land can be levelled and subsoiled in preparation for an arable crop or grass sowing.

3.4 Mineral development

Mineral developments necessarily require disturbance of the soil. There is UK Government guidance on requirements to support a mineral site planning application and for the aftercare (UK Government, 2021a).

In the 1990s government funded research was undertaken to evaluate the condition of mineral sites restored to agricultural use (Defra, 2000). Over 40 sites were studied over a 5-year period and the effect of mineral working on soil physical characteristics examined. The study reported that at the end of the 5-year aftercare period the majority of sites with BMV agricultural land (prior to working) had maintained their quality at the end of the aftercare period.

Many of the recommendations of the Defra (2000) study form part of the guidance on restoration of mineral workings to agricultural use (UK Government, 2021). Planning applications should be supported by a restoration plan with a soil resource report, a soil handling plan and soil storage proposals, all supported by detailed record keeping. An outline strategy for aftercare is expected and can be subject to a planning condition.

The established code of practice for the sustainable use of soils on construction sites (Defra,2009a) also covers aspects of soil stripping and storage for sites other than specific mineral extraction sites.

While following good practice is required to achieve restoration of land, there are situations, for example the prevailing ground conditions or loss of soil resource, which may affect the quality of land restoration. Despite best efforts restored land may be of a lower quality than the original.

4 SUMMARY

There are few in-field research studies undertaken on the impact of solar PV sites on agricultural land and soils, in the UK or internationally. The focus of research has been on the net environmental gains because of the land use change typically from intensive agricultural use to grassland on solar PV sites. Similar changes in land use are not exclusive to solar PV sites. The long-term potential impact on agricultural land and soils has not been tested or considered in detail. This is largely because solar PV sites are recent developments but also because in the early years sites were located on brownfield land or poorer quality agricultural land. The potential to achieve successful restoration of solar PV sites has increased in significance as the number, size and operational timeframe of solar PV sites on BMV agricultural land has increased.

Decommissioning of sites is an expanding area of work, particularly in the USA. In the UK plans are usually prepared near (within 6 months) of the end of life for the site (up to 40yrs). However, the requirements for a successful outcome of a decommissioning plan need to be identified at an early stage. Information at the pre-construction stage would form a useful baseline and inform the most suitable restoration requirements. This would include specifying essential requirements for soil treatment that would be necessary to undertake during the solar PV construction phase to preserve soils and their quality.

The reversibility of land from golf course use to an agricultural use has been reported, but there is no detail of the agricultural land quality attained. The removal of glasshouses and orchard grubbing generally have minimal impact on the land and soil.

Research carried out on mineral sites restored to agricultural use has considered soil physical characteristics. Guidance on the restoration of mineral workings to agricultural use set out the requirements for a soil resource plan to form part of the site working strategy at the application stage. There is a code for best practice when working with soils on construction sites to ensure sustainability of the soil resource.

The term '*reversibility*' is widely used in the context of solar PV development literature and planning applications. The terminology of reversibility, replacement and restoration in the context of solar PV sites should be explored.

There are reports of site suitability analysis using GIS both in the UK and internationally. The availability of strategic Agricultural Land Classification maps (Palmer,2019) in England limits studies. In Wales the Predictive Agricultural Land Classification map (Welsh Government 2021), shows a spilt of Grade 3 land (3a and 3b).

There are no published studies on the reversibility of solar PV sites and the impact of developments on agricultural land and soil.

5 CONCLUSIONS

The literature review has identified the following gaps:

- The need for the use of a site suitability and GIS analysis approach to include soil types and agricultural land quality, identifying BMV agricultural land (Grade 1, 2 and 3a) in England.
- The need for in-field research studies in the UK on solar PV sites or simulated sites of the impact on agricultural land and soil (physical characteristics) on a range of soil types and with a range of climatic limitations. This would need to cover the construction, operation, decommissioning and post-decommissioning phases.
- The need to review the known benefits to soil and land from other studies and their transferability to the solar PV site situation with a comparison of the benefits during site operation (e.g. carbon/structure/biodiversity) and the likely position after decommissioning and change in land management.
- An understanding of recovery times for any impacted soil physical characteristics after installation and decommissioning.
- An agreed definition of reversibility in the context of guidance and monitoring of sites is required.
- Need for best practice working guidelines throughout the life of solar PV sites.

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