LAND NORTH OF
LITTLE CHEVENEY FARM,
SHEEPHURST LANE,
MARDEN, KENT

AGRICULTURAL PROOF OF EVIDENCE
ON BEHALF OF
THE APPELLANT
BY

TONY KERNON BSc (Hons), MRICS, MBIAC

VOLUME 2: APPENDICES

LPA Reference: 22/501335/FUL

December 2023

KERNON
COUNTRYSIDE
CONSULTANTS
LIMITED

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Authorised By APK 12/23

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Curriculum Vitae

KERNON COUNTRYSIDE CONSULTANTS LIMITED

CURRICULUM VITAE

ANTHONY PAUL KERNON

SPECIALISMS

- Assessing the impacts of development proposals on agricultural land and rural businesses
- Agricultural building and dwelling assessments
- Equestrian building and dwelling assessments (racing, sports, rehabilitation, recreational enterprises)
- Farm and estate diversivification and development
- Inputs to Environmental Impact Assessment
- Expert witness work

SYNOPSIS

Tony is a rural surveyor with 35 years experience in assessing agricultural land issues, farm and equestrian businesses and farm diversification proposals, and the effects of development proposals on them. Brought up in rural Lincolnshire and now living on a small holding in Wiltshire, he has worked widely across the UK and beyond. He is recognised as a leading expert nationally in this subject area. Married with two children. Horse owner.

Tony's specialism is particularly in the following key areas:

- assessing the need for agricultural and equestrian development, acting widely across the UK for applicants and local planning authorities alike;
- farm development and diversification planning work, including building reuse and leisure development, Class Q, camping etc;
- assessing development impacts, including agricultural land quality and the policy implications of losses of farmland due to residential, commercial, solar or transport development, and inputs to Environmental Assessment;
- and providing expert evidence on these matters to Planning Inquiries and Hearings, court or arbitrations.

QUALIFICATIONS

Bachelor of Science Honours degree in Rural Land Management, University of Reading (BSc(Hons)). 1987. Awarded 2:1.
Diploma of Membership of the Royal Agricultural College (MRAC).
Professional Member of the Royal Institution of Chartered Surveyors (MRICS) (No. 81582). (1989).

OTHER PROFESSIONAL ACTIVITIES

Co-opted member of the Rural Practice Divisional Council of the Royal Institution of Chartered Surveyors. (1994 - 2000)
Member of the RICS Planning Practice Skills Panel (1992-1994)
Member of the RICS Environmental Law and Appraisals Practice Panel (1994 - 1997).
Fellow of the British Institute of Agricultural Consultants (FBIAC) (1998 onwards, Fellow since 2004).
Secretary of the Rural Planning Division of the British Institute of Agricultural Consultants (BIAC) (1999 – 2017).
Vice-Chairman of the British Institute of Agricultural Consultants (2019 – 2020)
Chairman of the British Institute of Agricultural Consultants (2020 – 2022)

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Purton Stoke, Swindon SN5 4LL
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Website: www.kernon.co.uk*

EXPERIENCE AND APPOINTMENTS

1997 ------>	**Kernon Countryside Consultants.** Principal for the last 25 years of agricultural and rural planning consultancy specialising in research and development related work. Specialisms include essential dwelling and building assessments, assessing the effects of development on land and land-based businesses, assessing the effects of road and infrastructure proposals on land and land-based businesses, and related expert opinion work. Tony specialises in development impact assessments, evaluating the effects of development (residential, solar, road etc) on agricultural land, agricultural land quality, farm and other rural businesses.
1987 - 1996	**Countryside Planning and Management**, Cirencester. In nearly ten years with CPM Tony was involved in land use change and environmental assessment studies across the UK and in Europe. From 1995 a partner in the business.
1983 - 1984	**Dickinson Davy and Markham**, Brigg. Assistant to the Senior Partner covering valuation and marketing work, compulsory purchase and compensation, and livestock market duties at Brigg and Louth.

RECENT RELEVANT EXPERIENCE

TRAINING COURSES

Landspreading of Non Farm Wastes. Fieldfare training course, 24 – 25 November 2009
Foaling Course. Twemlows Hall Stud Farm, 28 February 2010
Working with Soil: Agricultural Land Classification. 1 – 2 November 2017

TRANSPORT ENVIRONMENTAL ASSESSMENT CONTRIBUTIONS

1992	**Port Wakefield Channel Tunnel Freight Terminal, Yorkshire**
1993	**A1(M) Widening, Junctions 1-6 (Stage 2)**
1994 - 1995	**A55 Llanfairpwll to Nant Turnpike, Anglesey (Stage 3)**
1994 - 1995	**A479(T) Talgarth Bypass, Powys (Stage 3)**
1995	**Kilkhampton bypass (Stage 2)**
1997	**A477 Bangeston to Nash improvement, Pembroke**
2000	**Ammanford Outer Relief Road**
2001	**A421 Great Barford Bypass**
2001	**Boston Southern Relief Road**
2003	**A40 St Clears - Haverfordwest**
2003	**A470 Cwmbrach – Newbridge on Wye**
2003	**A11 Attleborough bypass**
2003 - 2008	**A487 Porthmadog bypass (Inquiry 2008)**
2004	**A55 Ewloe Bypass**
2004	**A40 Witney – Cogges link**
2005 – 2007	**A40 Robeston Wathen bypass (Inquiry 2007)**
2005 – 2007	**East Kent Access Road (Inquiry 2007)**
2006	**M4 widening around Cardiff**
2007 – 2008	**A40 Cwymbach to Newbridge (Inquiry 2008)**
2007	**A483 Newtown bypass**
2008 – 2009	**A470/A483 Builth Wells proposals**
2009 – 2017	**A487 Caernarfon-Bontnewydd bypass (Inquiry 2017)**
2009 – 2010	**North Bishops Cleeve extension**
2009 – 2010	**Land at Coombe Farm, Rochford**
2009 – 2011	**A477 St Clears to Red Roses (Inquiry 2011)**
2010 – 2011	**Streethay, Lichfield**
2010 – 2012	**A465 Heads of the Valley Stage 3 (Inquiry 2012)**
2013 – 2016	**A483/A489 Newtown Bypass mid Wales (Inquiry 2016)**
2013 - 2016	**High Speed 2 (HS2) rail link, Country South and London: Agricultural Expert for HS2 Ltd**

2015 – 2017 A487 Dyfi Bridge Improvements
2016 – 2018 A465 Heads of the Valley Sections 5 and 6 (Inquiry 2018)
2017 - 2018 A40 Llanddewi Velfrey to Penblewin
2017 – 2018 A4440 Worcester Southern Relief Road
2019 – 2020 A40 Penblewin to Red Roses
2019 – 2020 A55 Jn 15 and 16 Improvements

NSIP/DCO SOLAR INPUTS

2020 – 2022 Heckington Fen, Lincolnshire
Mallards Pass, Lincolnshire/Rutland
Penpergwm, Monmouthshire
Parc Solar Traffwll, Anglesey
Alaw Mon, Anglesey
Parc Solar Caenewydd, Swansea

EXPERT EVIDENCE GIVEN AT PUBLIC INQUIRIES AND HEARINGS

1992	**Brooklands Farm**: Buildings reuse	**Bonehill Mill Farm**: New farm building
	Chase Farm, Maldon: Romoval of condition	
1993	**Haden House**: Removal of condition	**Manor Farm**: New farm dwelling
1994	**Brooklands Farm**: 2nd Inquiry (housing)	**Cameron Farm**: Mobile home
	Barr Pound Farm: Enforcement appeal	**Land at Harrietsham**: Enforcement appeal
	Fortunes Farm Golf Course: Agric effects	
1995	**Village Farm**: New farm dwelling	**Attlefield Farm**: Size of farm dwelling
	Claverdon Lodge: Building reuse	**Bromsgrove Local Plan**: Housing allocation
	Harelands Farm: Barn conversion	**Lichfield Local Plan**: Against MAFF objection
	Castle Nurseries: Alternative site presentation	**Hyde Colt**: Mobile home / glasshouses
1996	**Church View Farm**: Enforcement appeal	**Highmoor Farm**: New farm dwelling
	Flecknoe Farm: Second farm dwelling	**Gwenfa Fields**: Removal of restriction
1997	**Basing Home Farm**: Grain storage issue	**Yatton**: Horse grazing on small farm
	Viscar Farm: Need for farm building / viability	**Newbury Local Plan**: Effects of development
	Lane End Mushroom Farm: Need for dwelling	
1998	**Moorfields Farm**: New farm dwelling	**Two Burrows Nursery**: Building retention
	Maidstone Borough LPI: Effects of dev'ment	**Dunball Drove**: Need for cattle incinerator
	Glenfield Cottage Poultry Farm: Bldg reuse	
1999	**Holland Park Farm**: Farm dwelling / calf unit	**Lambriggan Deer Farm**: Farm dwelling
	Northington Farm: Existing farm dwelling	
2000	**Twin Oaks Poultry Unit**: Traffic levels	**Coldharbour Farm**: Buildings reuse
	Meadows Poultry Farm: Farm dwelling	**Heathey Farm**: Mobile home
	Hazelwood Farm: Beef unit and farm dwelling	**Wheal-an-Wens**: Second dwelling
	Shardeloes Farm: Farm buildings	**Apsley Farm**: Buildings reuse
	Aylesbury Vale Local Plan: Site issues	**Home Farm**: Size of grainstore
	Deptford Farm: Buildings reuse	**A34/M4 Interchange**: Agricultural evidence
2001	**Lambriggan Deer Farm**: Farm dwelling	**Weyhill Nursery**: Second dwelling
	Blueys Farm: Mobile home	**Mannings Farm**: Farm dwelling
2002	**A419 Calcutt Access**: Effect on farms	**Land Adj White Swan**: Access alteration
	Cobweb Farm: Buildings reuse / diversification	**Happy Bank Farm**: Lack of need for building
	Philips Farm: Farm dwelling	**Lower Park Farm**: Building reuse / traffic
	West Wilts Local Plan Inquiry: Dev site	**Stourton Hill Farm**: Diversification
	Manor Farm: Building reuse	
2003	**Fairtrough Farm**: Equine dev and hay barn	**Darren Farm**: Impact of housing on farm
	Hollies Farm: Manager's dwelling	**Greenways Farm**: Farm diversification
	Land at Springhill: Certificate of lawfulness	**Land at Four Marks**: Dev site implications
	Oak Tree Farm: Mobile home	
2004	**Chytane Farm**: Objector to farm dwelling	**Oldberrow Lane Farm**: Relocation of buildings
	Crown East: Visitor facility and manager's flat	**Forestry Building, Wythall**: Forestry issues
	Swallow Cottage: Widening of holiday use	**Lower Dadkin Farm**: Mobile home

	Etchden Court Farm: New enterprise viability	**Villa Vista**: Viability of horticultural unit
	Attleborough Bypass: On behalf of Highways Agency	
2005	**Howells School**: Use of land for horses	**Newton Lane**: Enforcement appeal
	Otter Hollow: Mobile home	**Manor Farm**: Change of use class
	Springfield Barn: Barn conversion	**South Hatch Stables**: RTE refurbishment
	Ashley Wood Farm: Swimming pool	**Trevaskis Fruit Farm**: Farm dwelling
	The Hatchery: Mobile home	**Tregased**: Enforcement appeal
	Stockfields Farm: Building reuse	
2006	**Manor Farm**: Replacement farmhouse	**Bhaktivedanta Manor**: Farm buildings
	Sough Lane: Farm dwelling	**Military Vehicles**: Loss of BMV land
	Whitewebbs Farm: Enforcement appeal	**Ermine Street Stables**: Enforcement appeal
	Land at Condicote: Farm dwelling	**Featherstone Farm**: Replacement buildings
	Rye Park Farm: Enforcement appeal	**Flambards**: Mobile home and poultry unit
	Woodrow Farm: Buildings reuse	**Manor Farm**: Effect of housing on farm
	Rectory Farm: Retention of unlawful bldg	**Goblin Farm**: Arbitration re notice to quit
	Walltree Farm: Retention of structures	**Terrys Wood Farm**: Farm dwelling
	Weeford Island: Land quality issues	**Etchden Court Farm**: Mobile home
	College Farm: Relocation of farmyard	**Hollowshot Lane**: Farm dwelling and buildings
2007	**Woolly Park Farm**: Manager's dwelling	**Barcroft Hall**: Removal of condition
	Park Gate Nursery: Second dwelling	**Kent Access Road**: Effect on farms
	Penyrheol las: Retention of bund	**Greys Green Farm**: Enforcement appeal
	Hucksholt Farm: New beef unit in AONB	**A40 Robeston Wathen bypass**: Underpass
	The Green, Shrewley: Mobile home	**Woodland Wild Boar**: Mobile homes
	Brook Farm: Retention of polytunnels	
2008	**Weights Farm**: Second dwelling	**Whitegables**: Stud manager's dwelling
	Hill Farm: Mobile home	**Balaton Place**: Loss of paddock land
	Relocaton of Thame Market: Urgency issues	**Point to Point Farm**: Buildings / farm dwelling
	Spinney Bank Farm: Dwelling / viability issues	**Norman Court Stud**: Size of dwelling
	Higham Manor: Staff accommodation	**High Moor**: Temporary dwelling
	Robeston Watham bypass: Procedures Hearing	**Land at St Euny**: Bldg in World Heritage Area
	Monks Hall: Covered sand school	**Baydon Meadow**: Wind turbine
	Porthmadog bypass: Road scheme inquiry	
2009	**Claverton Down Stables**: New stables	**Meadow Farm**: Building conversion
	Hailsham Market: Closure issues	**Bishop's Castle Biomass Power Station**: Planning issues
	Gambledown Farm: Staff dwelling	**Foxhills Fishery**: Manager's dwelling
	Oak Tree Farm: Farm dwelling	**Bryn Gollen Newydd**: Nuisance court case
	A470 Builth Wells: Off line road scheme	**Swithland Barn**: Enforcement appeal
	Hill Top Farm: Second dwelling	**Woodrow Farm**: Retention of building
	Sterts Farm: Suitability / availability of dwelling	
2010	**Poultry Farm, Christmas Common**: Harm to AONB	**Stubwood Tankers**: Enforcement appeal
	Wellsprings: Rention of mobile home	**Meridian Farm**: Retention of building
	Redhouse Farm: Manager's dwelling	**Swithland Barn**: Retention of building
	Lobbington Fields Farm: Financial test	
2011	**Fairtrough Farm**: Enforcement appeal	**A477 Red Roses to St Clears**: Public Inquiry
	Etchden Court Farm: Farm dwelling	**Upper Bearfield Farm**: Additional dwelling
	Trottiscliffe Nursery: Mobile home	**North Bishops Cleeve**: Land quality issues
2012	**Tickbridge Farm**: Farm dwelling	**Langborrow Farm**: Staff dwellings
	Blaenanthir Farm: Stables and sandschool	**Heads of the Valley S3**: Improvements
	Land at Stonehill: Eq dentistry / mobile home	**Seafield Pedigrees**: Second dwelling
	Cwmcoedlan Stud: Farm dwelling with B&B	**Beedon Common**: Permanent dwelling
2013	**Barnwood Farm**: Farm dwelling	**Upper Youngs Farm**: Stables / log cabin
	Spring Farm Barn: Building conversion	**Tithe Barn Farm**: Enforcement appeal
	Baydon Road: Agricultural worker's dwelling	**Lower Fox Farm**: Mobile home / building

	Stapleford Farm: Building reuse	**Tewinbury Farm**: Storage barn
	Meddler Stud: Residential development	**Church Farm**: Solar park construction
	Deer Barn Farm: Agricultural worker's dwelling	
2014	**Land at Stow on the Wold**: Housing site	**Land at Elsfield**: Retention of hardstanding
	Allspheres Farm: Cottage restoration	**Queensbury Lodge**: Potential development
	Land at Stonehill: Equine dentistry practice	**Kellygreen Farm**: Solar park development
	Spring Farm Yard: Permanent dwelling	**Spring Farm Barn**: Building conversion
	Land at Valley Farm: Solar park	**Land at Willaston**: Residential development
	Land at Haslington: Residential development	**Bluebell Cottage**: Enforcement appeal
	Manor Farm: Solar farm on Grade 2 land	**Clemmit Farm**: Mobile home
	Penland Farm: Residential development	**Honeycrock Farm**: Farmhouse retention
	Sandyways Nursery: Retention of 23 caravans	**The Mulberry Bush**: Farm dwelling
2015	**The Lawns**: Agricultural building / hardstanding	**Redland Farm**: Residential dev issues
	Harefield Stud: Stud farm / ag worker's dwelling	**Emlagh Wind Farm**: Effect on equines
	Newtown Bypass: Compulsory purchase orders	**Fox Farm**: Building conversion to 2 dwellings
	Barn Farm: Solar farm	**Wadborough Park Farm**: Farm buildings
	Hollybank Farm: Temporary dwelling renewal	**Delamere Stables**: Restricted use
	Five Oaks Farm: Change of use of land and temporary dwelling	
2016	**Clemmit Farm**: Redetermination	**Meddler Stud**: RTE and up to 63 dwellings
	The Lawns: Replacement building	**Land off Craythorne Road**: Housing dev
	Land at the Lawns: Cattle building	**Berkshire Polo Club**: Stables / accomm
2017	**Low Barn Farm**: Temporary dwelling	**Harcourt Stud**: Temporary dwelling
	High Meadow Farm: Building conversion	**Clemmit Farm**: Second redetermination
	Windmill Barn: Class Q conversion	**Stonehouse Waters**: Change of use of lake
	Land at Felsted: Residential development	
2018	**Thorney Lee Stables**: Temporary dwelling	**Watlington Road**: Outline app residential
	Benson Lane: Outline app residential	**A465 Heads of the Valley 5/6**: Agric effects
	Park Road, Didcot: Outline app residential	**The Old Quarry**: Permanent dwelling
	Coalpit Heath: Residential development	**Chilaway Farm**: Removal of condition
2019	**Mutton Hall Farm**: Agric worker's dwelling	**Leahurst Nursery**: Temporary dwelling
	Clemmit Farm: Third redetermination	**Icomb Cow Pastures**: Temp mobile home
	Ten Acre Farm: Enforcement appeal	**Forest Faconry**: Construction of hack pens
	Harrold: 94 Residential dwellings	
2020	**Stan Hill**: Temp dwelling/agric. buildings	**Hazeldens Nursery**: Up to 84 extra care units
	Allspheres Farm: Enlargement of farm dwelling	**Leahurst Nursery**: Agricultural storage bldg
2021	**Ruins:** Dwelling for tree nursery	**Sketchley Lane, Burbage**: Industrial and residential development
2022	**Thornbury**: Local BMV	**Park Solar Traffwl**: Solar Hearing
	Penpergwym: Solar Farm Hearing	
2023	**Mudds Bank**: Equestrian workers dwelling	**Scruton Solar Farm**: Effects on BMV and food
	Mallard Pass NSIP: Issue specific hearing	**Land at East Burnham**: Equestrian facilities
	Bramford Solar: Loss of BMV / food	**Fladbury**: Housing on BMV land
	Gate Burton NSIP: BMV and Food	**Pound Road, Axminster**: BESS and BMV
	Heckington Fen NSIP: Issue Hearing	**Wymondley Solar**: Use of BMV
	Cutlers Green Solar: Use of BMV	

Appendix KCC2

Natural England Technical Information Note TIN049

Natural England Technical Information Note TIN049

Agricultural Land Classification: protecting the best and most versatile agricultural land

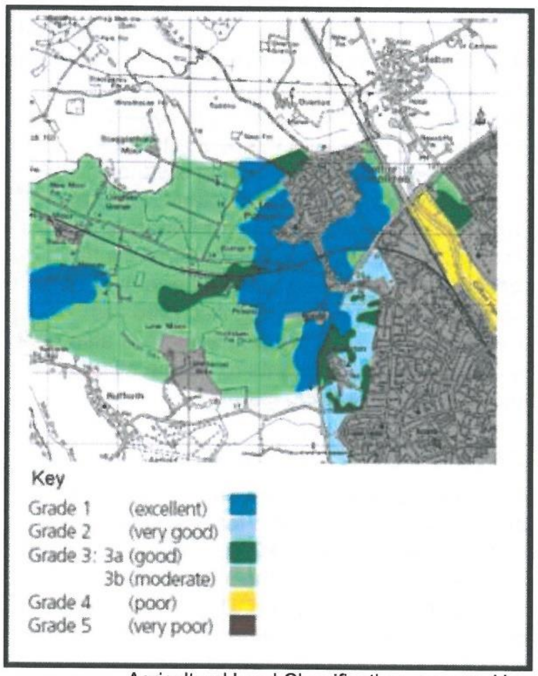
Most of our land area is in agricultural use. How this important natural resource is used is vital to sustainable development. This includes taking the right decisions about protecting it from inappropriate development.

Policy to protect agricultural land

Government policy for England is set out in the National Planning Policy Framework (NPPF) published in March 2012 (paragraph 112). Decisions rest with the relevant planning authorities who should take into account the economic and other benefits of the best and most versatile agricultural land. Where significant development of agricultural land is demonstrated to be necessary, local planning authorities should seek to use areas of poorer quality land in preference to that of higher quality. The Government has also re-affirmed the importance of protecting our soils and the services they provide in the Natural Environment White Paper The Natural Choice:securing the value of nature (June 2011), including the protection of best and most versatile agricultural land (paragraph 2.35).

The ALC system: purpose & uses

Land quality varies from place to place. The Agricultural Land Classification (ALC) provides a method for assessing the quality of farmland to enable informed choices to be made about its future use within the planning system. It helps underpin the principles of sustainable development.



Agricultural Land Classification - map and key

Second edition 19 December 2012

www.naturalengland.org.uk

NATURAL ENGLAND

Agricultural Land Classification: protecting the best and most versatile agricultural land

The ALC system classifies land into five grades, with Grade 3 subdivided into Subgrades 3a and 3b. The best and most versatile land is defined as Grades 1, 2 and 3a by policy guidance (see Annex 2 of NPPF). This is the land which is most flexible, productive and efficient in response to inputs and which can best deliver future crops for food and non food uses such as biomass, fibres and pharmaceuticals. Current estimates are that Grades 1 and 2 together form about 21% of all farmland in England; Subgrade 3a also covers about 21%.

The ALC system is used by Natural England and others to give advice to planning authorities, developers and the public if development is proposed on agricultural land or other greenfield sites that could potentially grow crops. The Town and Country Planning (Development Management Procedure) (England) Order 2010 (as amended) refers to the best and most versatile land policy in requiring statutory consultations with Natural England. Natural England is also responsible for Minerals and Waste Consultations where reclamation to agriculture is proposed under Schedule 5 of the Town and Country Planning Act 1990 (as amended). The ALC grading system is also used by commercial consultants to advise clients on land uses and planning issues.

Criteria and guidelines

The Classification is based on the long term physical limitations of land for agricultural use. Factors affecting the grade are climate, site and soil characteristics, and the important interactions between them. Detailed guidance for classifying land can be found in: *Agricultural Land Classification of England and Wales: revised guidelines and criteria for grading the quality of agricultural land* (MAFF, 1988):

- **Climate:** temperature and rainfall, aspect, exposure and frost risk.
- **Site:** gradient, micro-relief and flood risk.
- **Soil:** texture, structure, depth and stoniness, chemical properties which cannot be corrected.

The combination of climate and soil factors determines soil wetness and droughtiness. Wetness and droughtiness influence the choice of crops grown and the level and consistency of yields, as well as use of land for grazing livestock. The Classification is concerned with the inherent potential of land under a range of farming systems. The current agricultural use, or intensity of use, does not affect the ALC grade.

Versatility and yield

The physical limitations of land have four main effects on the way land is farmed. These are:

- the range of crops which can be grown;
- the level of yield;
- the consistency of yield; and
- the cost of obtaining the crop.

The ALC gives a high grading to land which allows more flexibility in the range of crops that can be grown (its 'versatility') and which requires lower inputs, but also takes into account ability to produce consistently high yields of a narrower range of crops.

Availability of ALC information

After the introduction of the ALC system in 1966 the whole of England and Wales was mapped from reconnaissance field surveys, to provide general strategic guidance on land quality for planners. This Provisional Series of maps was published on an Ordnance Survey base at a scale of One Inch to One Mile in the period 1967 to 1974. These maps are not sufficiently accurate for use in assessment of individual fields or development sites, and should not be used other than as general guidance. They show only five grades: their preparation preceded the subdivision of Grade 3 and the refinement of criteria, which occurred after 1976. They have not been updated and are out of print. A 1:250 000 scale map series based on the same information is available. These are more appropriate for the strategic use originally intended and can be downloaded from the Natural England **website**. This data is also available on 'Magic', an interactive, geographical information website **http://magic.defra.gov.uk/**.

Since 1976, selected areas have been re-surveyed in greater detail and to revised guidelines and criteria. Information based on detailed ALC field surveys in accordance with current guidelines (MAFF, 1988) is the most definitive source. Data from the former Ministry of Agriculture, Fisheries and Food (MAFF) archive of more detailed ALC survey information (from 1988) is also available on **http://magic.defra.gov.uk/**. Revisions to the ALC guidelines and criteria have been limited and kept to the original principles, but some assessments made prior to the most recent revision in 1988 need to be checked against current criteria. More recently, strategic scale maps showing the likely occurrence of best and most versatile land have been prepared. Mapped information of all types is available from Natural England (see *Further information* below).

New field survey

Digital mapping and geographical information systems have been introduced to facilitate the provision of up-to-date information. ALC surveys are undertaken, according to the published Guidelines, by field surveyors using handheld augers to examine soils to a depth of 1.2 metres, at a frequency of one boring per hectare for a detailed assessment. This is usually supplemented by digging occasional small pits (usually by hand) to inspect the soil profile. Information obtained by these methods is combined with climatic and other data to produce an ALC map and report. ALC maps are normally produced on an Ordnance Survey base at varying scales from 1:10,000 for detailed work to 1:50 000 for reconnaissance survey

There is no comprehensive programme to survey all areas in detail. Private consultants may survey land where it is under consideration for development, especially around the edge of towns, to allow comparisons between areas and to inform environmental assessments. ALC field surveys are usually time consuming and should be initiated well in advance of planning decisions. Planning authorities should ensure that sufficient detailed site specific ALC survey data is available to inform decision making.

Consultations

Natural England is consulted by planning authorities on the preparation of all development plans as part of its remit for the natural environment. For planning applications, specific consultations with Natural England are required under the Development Management Procedure Order in relation to best and most versatile agricultural land. These are for non agricultural development proposals that are not consistent with an adopted local plan and involve the loss of twenty hectares or more of the best and most versatile land. The land protection policy is relevant to all planning applications, including those on smaller areas, but it is for the planning authority to decide how significant the agricultural land issues are, and the need for field information. The planning authority may contact Natural England if it needs technical information or advice.

Consultations with Natural England are required on all applications for mineral working or waste disposal if the proposed afteruse is for agriculture or where the loss of best and most versatile agricultural land agricultural land will be 20 ha or more. Non-agricultural afteruse, for example for nature conservation or amenity, can be acceptable even on better quality land if soil resources are conserved and the long term potential of best and most versatile land is safeguarded by careful land restoration and aftercare.

Other factors

The ALC is a basis for assessing how development proposals affect agricultural land within the planning system, but it is not the sole consideration. Planning authorities are guided by the National Planning Policy Framework to protect and enhance soils more widely. This could include, for example, conserving soil resources during mineral working or construction, not granting permission for peat extraction from new or extended mineral sites, or preventing soil from being adversely affected by pollution. For information on the application of ALC in Wales, please see below.

Agricultural Land Classification: protecting the best and most versatile agricultural land

Further information

Details of the system of grading can be found in: *Agricultural Land Classification of England and Wales: revised guidelines and criteria for grading the quality of agricultural land* (MAFF, 1988).

Please note that planning authorities should send all planning related consultations and enquiries to Natural England by e-mail to **consultations@naturalengland.org.uk**. If it is not possible to consult us electronically then consultations should be sent to the following postal address:

Natural England
Consultation Service
Hornbeam House
Electra Way
Crewe Business Park
CREWE
Cheshire
CW1 6GJ

ALC information for Wales is held by Welsh Government. Detailed information and advice is available on request from Ian Rugg (**ian.rugg@wales.gsi.gov.uk**) or David Martyn (**david.martyn@wales.gsi.gov.uk**). If it is not possible to consult us electronically then consultations should be sent to the following postal address:

Welsh Government
Rhodfa Padarn
Llanbadarn Fawr
Aberystwyth
Ceredigion
SY23 3UR

Natural England publications are available to download from the Natural England website: **www.naturalengland.org.uk**.

For further information contact the Natural England Enquiry Service on 0300 060 0863 or e-mail **enquiries@naturalengland.org.uk**.

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Appendix KCC3

Extracts from the ALC Guidelines

Ministry of Agriculture, Fisheries and Food

Agricultural Land Classification

of

England and Wales

Revised guidelines and criteria for grading the quality of agricultural land

OCTOBER 1988

Agricultural Land Classification of England and Wales

CONTENTS

TABLES

TEXT FIGURES

PREFACE

This report provides revised guidelines and criteria for grading the quality of agricultural land using the Agricultural Land Classification (ALC) of England and Wales. The ALC was devised and introduced in the 1960s and Technical Report 11 (MAFF, 1966) outlined the national system, which forms the basis for advice given by the Ministry of Agriculture, Fisheries and Food (MAFF) and Welsh Office Agriculture Department (WOAD) on land use planning matters. Following a review of the system, criteria for the sub-division of Grade 3 were published in Technical Report 11/1 (MAFF, 1976). The classification is well established and understood in the planning system and provides an appropriate framework for determining the physical quality of the land at national, regional and local levels.

Experience gained has shown that some modifications to the ALC system can usefully be made to take advantage of new knowledge and data, to improve the objectivity and consistency of assessments and standardise terminology. The revised guidelines and criteria in this report have been developed and tested with the aim of updating the system without changing the original concepts. A further aim has been to calibrate the revised criteria with those used previously to maintain as far as possible the consistency of grading. The guidelines and methods used to define grades and subgrades are based on the best and most up to date information available but future revisions may be necessary to accommodate new information and technical innovation.

There is a continuing need to distinguish between the better land in Grade 3 and other land in this Grade but it is no longer considered necessary to maintain a threefold division. Two subgrades are now recognised: Subgrade 3a and Subgrade 3b, the latter being a combination of the previous Subgrades 3b and 3c.

Technical Report 11 included proposals for the development of an economic classification system linked to the physical classification. It also identified a number of significant disadvantages for a national system of economic classification, especially the problems associated with the acquisition of objective, up to date, accurate and consistent farm output data. No satisfactory means have been found of overcoming these problems and for this reason economic criteria for grading land have not been adopted. Similarly site specific crop yield data are not regarded as a reliable indication of land quality, because it is not possible to consistently make allowances for variables such as management skill, different levels of input and short-term weather factors.

The principal changes in this revision concern the criteria used to assess climatic limitations and the main limitations involving a climate-soil interaction, namely soil wetness and droughtiness. The revised methods have been developed and evaluated by the Agricultural Development and Advisory Service (ADAS) in close collaboration with the Soil Survey and Land Research Centre (SSLRC, incorporating the Soil Survey of England and Wales) and the Meteorological Office. A number of new and improved climatic datasets have been compiled on the same collaborative basis and these base data are held in LandIS, a computer information system funded by MAFF and developed by SSLRC. The datasets will also be published by the Meteorological Office (in press) and are described in Appendix 1.

The revised system incorporates some features of the 7-class Land Use Capability Classification formerly used by the Soil Survey of England and Wales (Bibby and Mackney, 1969) in which Classes 5, 6 and 7 broadly correspond to Grade 5 of the ALC system. In common with the Scottish Land Capability Classification for Agriculture (Bibby et al, 1982) some of the concepts now introduced originated from the ADAS Land Capability Working Party which met between 1974 and 1981. Although there are similarities with the Scottish system, the Agricultural Land Classification has been developed and calibrated specifically for use in England and Wales. This report describes the criteria and assessment methods which will be used by MAFF and WOAD to classify land. Wherever possible, definitions and methods common to both ADAS and SSLRC have been used.

Acknowledgements

The Ministry is indebted to the Meteorological Office and Soil Survey and Land Research Centre for their assistance, information and advice provided over a period of years. The climate-related components of the system were revised by a working group chaired by A J Hooper (ADAS) and the contributions of J H Minhinick and J F Keers (Meteorological Office), Dr R J A Jones and J M Hollis (SSLRC), D Hewgill, M R Watson and Dr I P Jones (ADAS) are gratefully acknowledged. Valuable assistance was also provided by F Broughton (ADAS). Evaluations and testing of the revised criteria were co-ordinated by M R Watson and carried out by regional staff of the Resource Planning Group, ADAS.

Ministry of Agriculture, Fisheries and Food
October 1988

SECTION 1

INTRODUCTION

The Agricultural Land Classification provides a framework for classifying land according to the extent to which its physical or chemical characteristics impose long-term limitations on agricultural use. The limitations can operate in one or more of four principal ways: they may affect the range of crops which can be grown, the level of yield, the consistency of yield and the cost of obtaining it. The classification system gives considerable weight to flexibility of cropping, whether actual or potential, but the ability of some land to produce consistently high yields of a somewhat narrower range of crops is also taken into account.

The principal physical factors influencing agricultural production are climate, site and soil. These factors together with interactions between them form the basis for classifying land into one of five grades; Grade 1 land being of excellent quality and Grade 5 land of very poor quality. Grade 3, which constitutes about half of the agricultural land in England and Wales, is now divided into two subgrades designated 3a and 3b. General descriptions of the grades and subgrades are given in Section 2.

Guidelines for the assessment of the physical factors which determine the grade of land are given in Section 3. The main climatic factors are temperature and rainfall although account is taken of exposure, aspect and frost risk. The site factors used in the classification system are gradient, microrelief and flood risk. Soil characteristics of particular importance are texture, structure, depth and stoniness. In some situations, chemical properties can also influence the long-term potential of land and are taken into account. These climatic, site and soil factors result in varying degrees of constraint on agricultural production. They can act either separately or in combination, the most important interactive limitations being soil wetness and droughtiness.

The grade or subgrade of land is determined by the most limiting factor present. When classifying land the overall climate and site limitations should be considered first as these can have an overriding influence on the grade. Land is graded and mapped without regard to present field boundaries, except where they coincide with permanent physical features.

A degree of variability in physical characteristics within a discrete area is to be expected. If the area includes a small proportion of land of different quality, the variability can be considered as a function of the mapping scale. Thus, small, discrete areas of a different ALC grade may be identified on large scale maps, whereas on smaller scale maps it may only be feasible to show the predominant grade. However, where soil and site conditions vary significantly and repeatedly over short distances and impose a practical constraint on cropping and land management a 'pattern' limitation is said to exist. This variability becomes a significant limitation if, for example, soils of the same grade but of contrasting texture occur as an extensive patchwork thus complicating soil management and cropping decisions or resulting in uneven crop growth, maturation or quality. Similarly, a form of pattern limitation may arise where soil depth is highly variable or microrelief restricts the use of machinery. Because many different combinations of characteristics can occur no specific guidelines are given for pattern limitations. The effect on grading is judged according to the severity of the limitations imposed by the pattern on cropping and management, and is mapped where permitted by the scale of the survey.

The guidelines provide a consistent basis for land classification but, given the complex and variable nature of the factors assessed and the wide range of circumstances in which they can occur, it is not possible to prescribe for every possible situation. It may sometimes be necessary to take account of special or local circumstances when classifying land. For this reason, the physical criteria of eligibility in this report are regarded as guidelines rather than rules although departures from the guidance should be exceptional and based on expert knowledge. Physical conditions on restored land may take several years to stabilise; therefore, the land is not normally graded until the end of the statutory aftercare period, or otherwise not until 5 years after soil replacement.

To ensure a consistent approach when classifying land the following assumptions are made:

1. Land is graded according to the degree to which physical or chemical properties impose long-term limitations on agricultural use. It is assessed on its capability at a good[1] but not outstanding standard of management.

2. Where limitations can be reduced or removed by normal management operations or improvements, for example cultivations or the installation of an appropriate underdrainage system, the land is graded according to the severity of the remaining limitations. Where an adequate supply of irrigation water is available this may be taken into account when grading the land (Section 3.4). Chemical problems which cannot be rectified, such as high levels of toxic elements or extreme subsoil acidity, are also taken into account.

3. Where long-term limitations outside the control of the farmer or grower will be removed or reduced in the near future through the implementation of a major improvement scheme, such as new arterial drainage or sea defence improvements, the land is classified as if the improvements have already been carried out. Where no such scheme is proposed, or there is uncertainty about implementation, the limitations will be taken into account. Where limitations of uncertain but potentially long-term duration occur, such as subsoil compaction or gas-induced anaerobism, the grading will take account of the severity at the time of survey.

4. The grading does not necessarily reflect the current economic value of land, land use, range of crops, suitability for specific crops or level of yield. For reasons given in the preface, the grade cut-offs are not specified on the basis of crop yields as these can be misleading, although in some cases crop growth may give an indication of the relative severity of a limitation.

5. The size, structure and location of farms, the standard of fixed equipment and the accessibility of land do not affect grading, although they may influence land use decisions.

[1] Previously described as 'satisfactory'; no change in the assumed standard of management is intended.

SECTION 2

DESCRIPTION OF THE GRADES AND SUBGRADES

The ALC grades and subgrades are described below in terms of the types of limitation which can occur, typical cropping range and the expected level and consistency of yield. In practice, the grades are defined by reference to physical characteristics and the grading guidance and cut-offs for limitation factors in Section 3 enable land to be ranked in accordance with these general descriptions. The most productive and flexible land falls into Grades 1 and 2 and Subgrade 3a and collectively comprises about one-third of the agricultural land in England and Wales. About half the land is of moderate quality in Subgrade 3b or poor quality in Grade 4. Although less significant on a national scale such land can be locally valuable to agriculture and the rural economy where poorer farmland predominates. The remainder is very poor quality land in Grade 5, which mostly occurs in the uplands.

Descriptions are also given of other land categories which may be used on ALC maps.

Grade 1 - excellent quality agricultural land
Land with no or very minor limitations to agricultural use. A very wide range of agricultural and horticultural crops can be grown and commonly includes top fruit, soft fruit, salad crops and winter harvested vegetables. Yields are high and less variable than on land of lower quality.

Grade 2 - very good quality agricultural land
Land with minor limitations which affect crop yield, cultivations or harvesting. A wide range of agricultural and horticultural crops can usually be grown but on some land in the grade there may be reduced flexibility due to difficulties with the production of the more demanding crops such as winter harvested vegetables and arable root crops. The level of yield is generally high but may be lower or more variable than Grade 1.

Grade 3 - good to moderate quality agricultural land
Land with moderate limitations which affect the choice of crops, timing and type of cultivation, harvesting or the level of yield. Where more demanding crops are grown yields are generally lower or more variable than on land in Grades 1 and 2.

Subgrade 3a - good quality agricultural land
Land capable of consistently producing moderate to high yields of a narrow range of arable crops, especially cereals, or moderate yields of a wide range of crops including cereals, grass, oilseed rape, potatoes, sugar beet and the less demanding horticultural crops.

Subgrade 3b - moderate quality agricultural land
Land capable of producing moderate yields of a narrow range of crops, principally cereals and grass or lower yields of a wider range of crops or high yields of grass which can be grazed or harvested over most of the year.

Grade 4 - poor quality agricultural land
Land with severe limitations which significantly restrict the range of crops and/or level of yields. It is mainly suited to grass with occasional arable crops (e.g. cereals and forage crops) the yields of which are variable. In moist climates, yields of grass may be moderate to high but there may be difficulties in utilisation. The grade also includes very droughty arable land.

Grade 5 - very poor quality agricultural land
Land with very severe limitations which restrict use to permanent pasture or rough grazing, except for occasional pioneer forage crops.

Descriptions of other land categories used on ALC maps

Urban
Built-up or 'hard' uses with relatively little potential for a return to agriculture including: housing, industry, commerce, education, transport, religious buildings, cemeteries. Also, hard-surfaced sports facilities, permanent caravan sites and vacant land; all types of derelict land, including mineral workings which are only likely to be reclaimed using derelict land grants.

Non-agricultural
'Soft' uses where most of the land could be returned relatively easily to agriculture, including: golf courses, private parkland, public open spaces, sports fields, allotments and soft-surfaced areas on airports/ airfields. Also active mineral workings and refuse tips where restoration conditions to 'soft' after-uses may apply.

Woodland
Includes commercial and non-commercial woodland. A distinction may be made as necessary between farm and non-farm woodland.

Agricultural buildings
Includes the normal range of agricultural buildings as well as other relatively permanent structures such as glasshouses. Temporary structures (e.g. polythene tunnels erected for lambing) may be ignored.

Open water
Includes lakes, ponds and rivers as map scale permits.

Land not surveyed
Agricultural land which has not been surveyed,

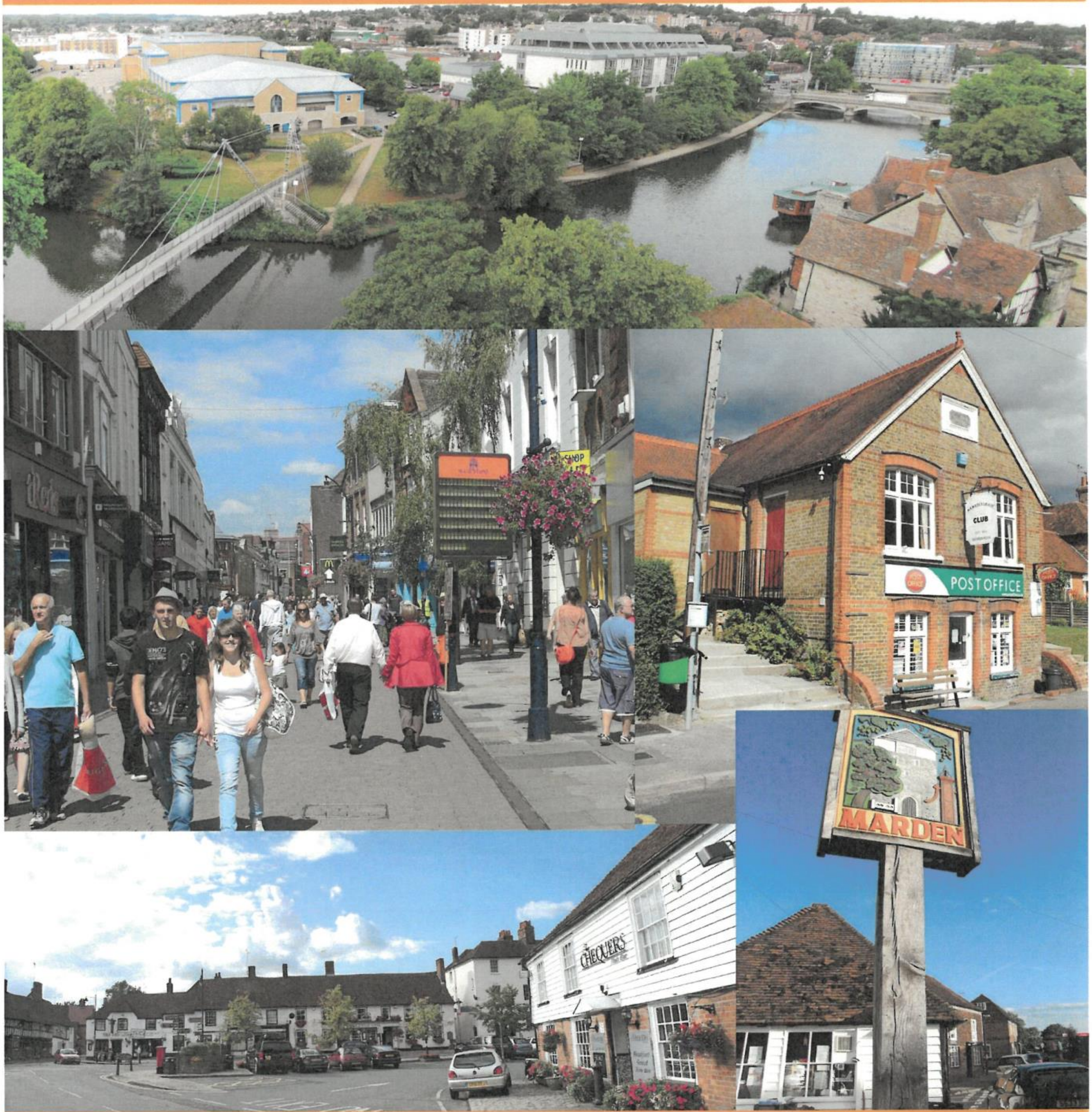
Where the land use includes more than one of the above land cover types, e.g. buildings in large grounds, and where map scale permits, the cover types may be shown separately. Otherwise, the most extensive cover type will usually be shown.

APPENDIX KCC4

MBC Policy Advice Note (2014)

Maidstone Borough Council

Planning policy advice note: Large scale (>50kW) solar PV arrays



www.maidstone.gov.uk/localplan

MAIDSTONE
Borough Council
Great People, Great Place, Great Opportunity

The development of a 1.4 MW solar PV farm on land adjacent to the Hendra Holiday Park, Newquay will assist in meeting the demand of this facility. Images courtesy of Hendra Holiday Park.

H - Assessment of the impact on agricultural land

3.17 The National Planning Policy Framework indicates that

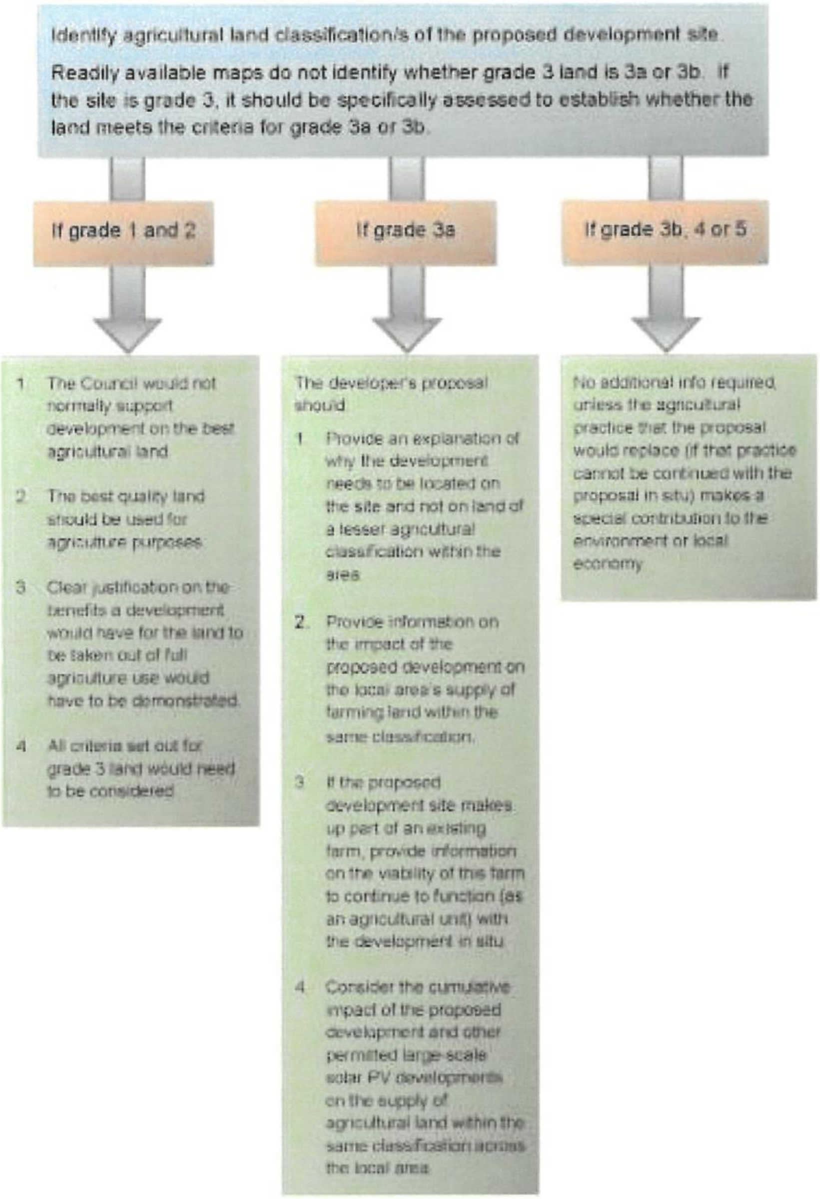
"Local planning authorities should take into account the economic and other benefits of the best and most versatile agricultural land. Where significant development of agricultural land is demonstrated to be necessary, local planning authorities should seek to use areas of poorer quality land in preference to that of a higher quality."

3.18 The presence of the best and most versatile agricultural land (defined as land in grades 1, 2 and 3a of the agricultural land classification) will therefore be a significant issue in the determination of applications to be taken into account alongside other sustainability considerations.

3.19 This position should be taken into account when identifying sites for large scale solar photovoltaic development. The following steps should be undertaken by the developer when considering locating a large scale solar photovoltaic development on agricultural land. If a planning application is subsequently submitted it should be accompanied by the relevant information detailed in the steps below.

Construction of a 1.4MW solar PV farm at the former tin mine site at Wheal Jane, Cornwall. Such sites should generally be considered for development in preference to agricultural land.

3 . Planning application considerations



Maidstone Borough Council's steps for developers on agricultural land classification.

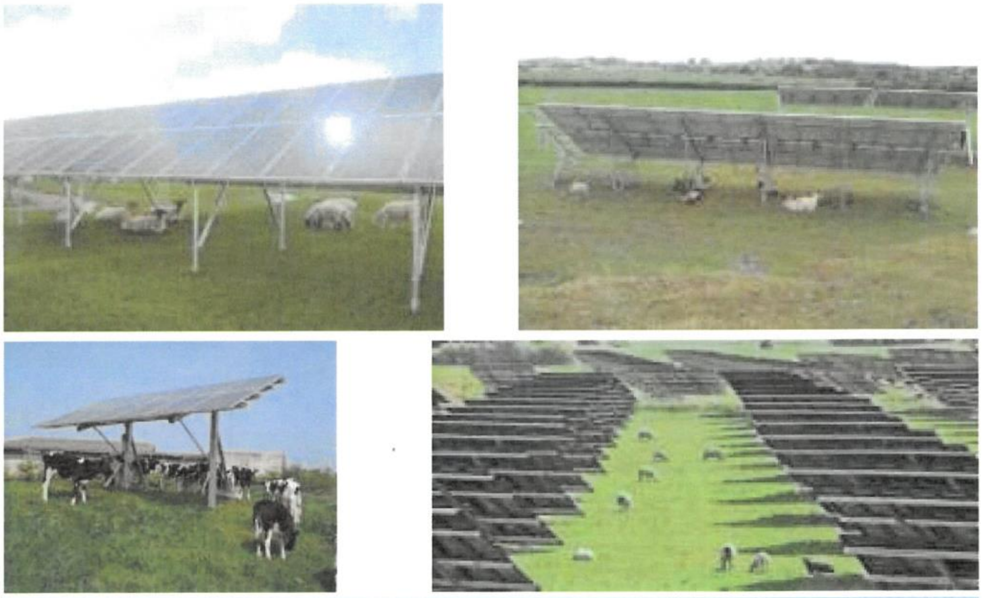
3 . Planning application considerations

I - Ground maintenance

3.20 Vegetation will grow under the solar panels and this will require management, particularly to avoid the site becoming overgrown with noxious weeds and assist with the eventual restoration of the site, normally to agriculture. There are various techniques for managing the vegetation, these include mowing, strimming, spraying or mulching.

3.21 Spraying should be avoided wherever possible and mulching large areas is likely to present technical challenges and may add to the landscape/visual impact of a development proposal. Few of these management techniques are regarded as sustainable, particularly on sites up to 15ha, and there is a desire, both in terms of food production and the rural scene, to continue an agricultural use on the site.

3.22 Grazing is therefore to be encouraged wherever practicable. Cattle, horses, pigs and goats are likely to be too 'physical' with the solar PV arrays but sheep, chickens or geese should be acceptable. In order to facilitate grazing within the solar farm it is advised that solar panels are positioned at least 900mm above ground level and all cabling etc. is suitably protected.



Sheep and cattle grazing under solar PV arrays. Support structures and the height of panels would need to be substantial in order to allow cattle grazing and would not ordinarily be recommended. Images courtesy of Steve Edmunds, Mole Valley Renewables.

APPENDIX KCC5

Agricultural Land Classification,

Reading Agricultural Consultants

(text and plans)

Reading Agricultural Consultants

March 2022

Statkraft UK Limited
Agricultural Land Classification and Soil Resources

of

Land off Sheephurst Lane, Marden, Kent

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Table of Contents

1 Introduction

1.1 Reading Agricultural Consultants Ltd (RAC) is instructed by Statkraft UK Limited to investigate the Agricultural Land Classification (ALC) and soil resources of land off Sheephurst Lane, Marden, Kent, by means of a detailed survey of soil and site characteristics.

1.2 Guidance for assessing the quality of agricultural land in England and Wales is set out in the Ministry of Agriculture, Fisheries and Food (MAFF) revised guidelines and criteria for grading the quality of agricultural land (1988)[1], and summarised in Natural England's Technical Information Note 049[2].

1.3 Agricultural land in England and Wales is graded between 1 and 5, depending on the extent to which physical or chemical characteristics impose long-term limitations on agricultural use. The principal physical factors influencing grading are climate, site and soil which, together with interactions between them, form the basis for classifying land into one of the five grades.

1.4 Grade 1 land is excellent quality agricultural land with very minor or no limitations to agricultural use. Grade 2 is very good quality agricultural land, with minor limitations which affect crop yield, cultivations or harvesting. Grade 3 land has moderate limitations which affect the choice of crops, timing and type of cultivation, harvesting or the level of yield, and is subdivided into Subgrade 3a (good quality land) and Subgrade 3b (moderate quality land). Grade 4 land is poor quality agricultural land with severe limitations which significantly restrict the range of crops and/or level of yields. Grade 5 is very poor quality land, with very severe limitations which restrict use to permanent pasture or rough grazing.

1.5 Land which is classified as Grades 1, 2 and 3a in the ALC system is defined in Annex 2 of the NPPF[3] as best and most versatile (BMV) agricultural land.

1.6 As explained in Natural England's TIN049, the whole of England and Wales was mapped from reconnaissance field surveys in the late 1960s and early 1970s, to provide general strategic guidance on agricultural land quality for planners. This Provisional Series of maps was published

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[1] **MAFF (1988).** *Agricultural Land Classification of England and Wales. Revised guidelines and criteria for grading the quality of agricultural land.* http://publications.naturalengland.org.uk/file/5526580165083136
[2] **Natural England (2012).** *Technical Information Note 049 - Agricultural Land Classification: protecting the best and most versatile agricultural land.* http://publications.naturalengland.org.uk/file/4424325
[3] **Ministry of Housing, Communities and Local Government (2021)**. *National Planning Policy Framework.* https://www.gov.uk/government/publications/national-planning-policy-framework--2

on an Ordnance Survey base at a scale of One Inch to One Mile (1:63,360). The Provisional ALC map shows the site undifferentiated Grade 3. However, TIN049 explains that:

> *"These maps are not sufficiently accurate for use in assessment of individual fields or development sites, and should not be used other than as general guidance. They show only five grades: their preparation preceded the subdivision of Grade 3 and the refinement of criteria, which occurred after 1976. They have not been updated and are out of print. A 1:250 000 scale map series based on the same information is available. These are more appropriate for the strategic use originally intended ..."*

1.7 TIN049 goes on to explain that a definitive ALC grading should be obtained by undertaking a detailed survey according to the published guidelines, at an observation density of one boring per hectare. This survey follows the detailed methodology set out in the ALC guidelines.

1.8 The site has not been surveyed previously, and the nearest detailed survey data to the north and east of Marden show that land in this locality has been classified as a mix of Grades 2, 3a and 3b.

2 Site and climatic conditions

General features, land form, drainage and flood risk

2.1 The site extends to approximately 74.5ha, comprising seven arable fields to the north of Sheephurst Lane and south of a railway line to the west of Marden. At the time of survey, the fields were cropped in winter beans or wheat with some grass margins in Countryside Stewardship.

2.2 Topography is level apart from a slight rise on land adjoining Sheephurst Lane. The land is 18m to 20m above Ordnance Datum (AOD). There are no gradient limitations to agricultural land quality.

2.3 Most of the land lies on or adjacent to a floodplain, though groundwater is well controlled by a network of quite deep functioning ditches.

Agro-climatic conditions

2.4 Agro-climatic data have been interpolated from the Meteorological Office's standard 5km grid point dataset at a representative altitude of 18m AOD, and are given in Table 1. The site is warm and drier than much of Kent, with large crop moisture deficits possible. The number of days when soil is at Field Capacity is slightly below average for lowland England (150) which makes the land favourable for agricultural field work. There is no overriding climatic limitation to agricultural land quality.

Table 1: Local agro-climatic conditions

Parameter	
Grid Reference	TQ 572495 144693
Average Annual Rainfall	671 mm
Accumulated Temperatures >0°C	1,492 day
Field Capacity Days	139 days
Average Moisture Deficit, wheat	124 mm
Average Moisture Deficit, potatoes	122 mm

Soil parent material and soil type

2.5 The underlying geology is mapped by the British Geological Survey[4] as Weald Clay described as dark grey, thinly-bedded mudstones (shales) and mudstones with subordinate siltstones and fine- to medium-grained sandstones, which include some shelly limestone layers. The last is shown on the rising land in the south-west of the site.

2.6 All the flat land within the site is shown as covered by superficial deposits, either of River Terrace clay and silt or Alluvium in the east.

2.7 The Soil Survey of England and Wales soil mapping[5] (1:250,000 scale) shows Shabbington association in the west of the site and Fladbury 3 association in the east. Shabbington association soils are fine loamy or silty passing to sandy or gravelly base, and are naturally subject to seasonal fluctuating waterlogging (Wetness Class (WC) III or IV). However, installation of effective drainage schemes can improve them to WC II or I. Fladbury 3 soils can have issues of slow permeability limiting improvement to WC III.

3 Agricultural land quality

Soil survey methods

3.1 In total, 93 soil profiles were examined using an arable gouge auger at an observation density of more than one per hectare which is greater than the established recommendations for ALC surveys[2]. Five soil pits were also excavated to examine structure and stone content. The locations of observations are indicated on Figure RAC/9221/1. At each observation point the

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[4] **British Geological Survey (2021).** *Geology of Britain viewer*, http://mapapps.bgs.ac.uk/geologyofbritain/home.html

[5] **Soil Survey of England and Wales (1984).** *Soils of South East England* (1:250,000), Sheet 6

following characteristics were assessed for each soil horizon up to a maximum of 120cm or any impenetrable layer:

- soil texture
- significant stoniness
- colour (including localised mottling)
- consistency
- structural condition
- free carbonate; and
- depth.

3.2 Six topsoil samples (composites 0-25cm depth) were submitted for laboratory determination of particle size distribution, pH, organic matter content and nutrient contents (P, K, Mg). Results are given in Appendix 1.

3.3 Soil nutrient levels are low in the west of the site and good in the east. Organic matter levels are mostly suboptimal for heavier soils. All the land has alkaline pH. These factors can be ameliorated and are not a basis for classifying the land. Minimal tillage is improving the structure in the surface but causing firmer blockier structures in the *lower* topsoil (14-28cm), Appendix 3.

3.4 Soil Wetness Class (WC) was determined from the matrix colour, presence or absence of, and depth to, greyish and ochreous gley mottling, and slowly permeable subsoil layers at least 15cm thick, in relation to the number of Field Capacity Days at the location.

3.5 Soil droughtiness was investigated by the calculation of moisture balance equations (given in Appendix 2). Crop-adjusted Available Profile Water (AP) is estimated from texture, stoniness and depth, and then compared to a calculated moisture deficit (MD) for the standard crops wheat and potatoes. The MD is a function of potential evapotranspiration and rainfall. Grading of the land is affected if the AP is insufficient to balance the MD and droughtiness occurs.

Agricultural land classification

3.6 Assessment of agricultural land quality has been carried out according to the MAFF revised ALC guidelines (1988)[1]. Soil profiles have been described according to Hodgson (1997)[6] which is the

[6] **Hodgson, J. M. (Ed.) (1997).** *Soil survey field handbook.* Soil Survey Technical Monograph No. 5, Silsoe.

recognised source for describing soil profiles and characteristics according to the revised ALC guidelines.

3.7 Plate 1 below shows soils according to superficial geology, differentiating between those formed on River Terrace deposits (C), on Alluvium (Y) and on Weald Clay (G). Medium topsoil textures for each type are shown as 2; heavier topsoil textures as 3; and clayey topsoil textures as 4.

Plate 1: Soil Types

3.8 The soil types are summarised below in the following table.

Table 2: Description of soil types

Code C2	Medium textured topsoil on River Terrace deposits
Topsoil	At least 28cm of stoneless or very slightly stony medium clay loam, brownish (2.5Y5/4 in the Munsell soil colour charts[7]).
Upper Subsoil	Clay loam, greyish brown or brown (2.5Y5/3 or 5/4) with some mottles overlying more compact manganiferous clay loam or clay starting at 35-45cm, which has restricted permeability.
Lower Subsoil	Friable permeable clay loam or sandy clay loam starts at 50-60cm, slightly stony with many manganese and grey mottles, dominant colour can be strong brown (7.5YR6/8). Passes to stonier sandy material within 1m.

[7] **Munsell Color (2009).** *Munsell Soil Color Book*. Grand Rapids, MI, USA

Limitations	The compact layer may be as little as 15cm thick and should respond to subsoiling. WC is II or III which, coupled with medium topsoil, sets ALC Grade at 2 or 3a. Droughtiness limits some profiles to 3a. See Appendix 3 pit F.
Code C3	**Heavier topsoil on River Terrace deposits**
Topsoil	At least 28cm of stoneless heavy (silty) clay loam, brownish (2.5Y4/4 or 5/4). Friable in top 10cm, firmer blocky beneath.
Upper Subsoil	Heavy clay loam, greyish brown (2.5Y5/3) with some mottles overlying a compact manganiferous clayey layer starting at 35-45cm, which is slowly permeable.
Lower Subsoil	Permeable clay loam or sandy clay loam starts at 50-60cm, slightly stony with many manganese and grey mottles, dominant colour can be strong brown (7.5YR6/8). Passes to stonier sandy material within 1m, locally clayey.
Limitations	Slowly permeable layer often less than 15cm thick which acts as a barrier to rooting (to beans) but could be remedied by subsoiler. WC is II which, coupled with heavy loam topsoil, gives ALC Grade 3a. See Appendix 3 pit E. Where the subsoil clay is thicker or in lower lying areas, profiles are WCIII and ALC Grade 3b.
Code Y3c	**Calcareous loam on Alluvium**
Topsoil	At least 25cm of heavy clay loam, brownish (10YR4/3). Slightly stony with small ironstones and limestones. Slightly calcareous. Friable.
Upper Subsoil	Below 35cm is silty clay loam without stones. Greyish brown (2.5Y5/3) with some mottles and manganese layers.
Lower Subsoil	Slowly permeable starting 80-105cm: heavy silty clay loam or grey calcareous (Weald) clay.
Limitations	WC is II which, coupled with calcareous heavy clay loam topsoil, sets ALC Grade at 2. Drought limits to Grade 2.
Code Y2	**Medium silt on Alluvium**
Topsoil	At least 28cm of stoneless medium silty clay loam, brownish (2.5Y4/4). Friable.
Upper Subsoil	Heavy silty clay loam, greyish brown (2.5Y5/2-5/6) with some mottles or manganese below 35cm. Locally contains a compact silty clay layer within 60cm.
Lower Subsoil	Friable mottled strong-brown ochreous + manganiferous (silty) clay loam, locally dark brown (mainly manganese). Heavy (silty) clay loam below 80cm.
Limitations	WC is II or III which, coupled with medium topsoil, sets ALC Grade at 2 or 3a. Drought limits to Grade 2.
Code Y3	**Heavier silt on Alluvium**
Topsoil	At least 28cm of heavy silty clay loam, brownish (2.5Y4/4 or 5/4). Stoneless (locally a few hard stones). Friable with firmer blocks in lower topsoil.
Upper Subsoil	Medium silty clay loam, greyish brown (2.5Y5/3-5/6) with some mottles over a compact manganiferous clayey layer starting at 35-45cm.
Lower Subsoil	Friable mottled strong-brown ochreous + manganiferous (silty) clay loam. Denser greyer clayey layers occur below 70cm. Locally, Weald Clay within 1m.
Limitations	The compact slowly permeable layer in upper subsoil is often < 15cm deep and can be subsoiled. WC is usually II but III where the clayey layers are more extensive. Coupled with heavier topsoil this sets ALC Grade at 3a, sometimes 3b.
Code Y4	**Clayey land on Alluvium**
Topsoil	About 25cm of stoneless silty clay, brownish (2.5Y4/4 or 5/4). Firm blocky structures, except in drill rows.
Upper	Clay or silty clay, varying from slightly mottled to common mottles (colour

Subsoil	2.5Y5/3-7/1). Slowly permeable within 35cm but of variable thickness (10 to 30cm).
Lower Subsoil	Friable mottled strong-brown (7.5YR6/8) manganiferous (silty) clay loam overlying within 80cm silty clay or greenish grey (7.5GY7/1) Weald clay, especially along north.
Limitations	Where compact slowly permeable in upper subsoil is < 15cm it can be subsoiled. According to clay depths, WC varies from II to IV but because of the clayey topsoil the land cannot be rated higher than ALC Grade 3b. See Appendix 3, pits A and B.
Code G2	**Medium soils on Weald Clay and limestone**
Topsoil	About 28cm of slightly stony medium clay loam, brownish (10YR4/4). Very friable.
Upper Subsoil	Clay start depth varies from 30 to 70cm, overlain by heavy silty clay loam. Upper subsoil is olive-brown (2.5Y5/6) with a few mottles, locally slightly calcareous.
Lower Subsoil	Clay, light (greenish) grey (10-7.5GY-7/1) with many ochreous/ manganese mottles. Slowly permeable; can contain very stony (limestone) layers within 80cm.
Limitations	WC III or II. Bean growth seems unrestricted. ALC Grade limited to 3a or 2 due to wetness and/or droughtiness. See Appendix 3 pit D.
Code G3	**Heavy land on Weald Clay (and Limestone)**
Topsoil	At least 25cm of stoneless heavy (silty) clay loam locally silty clay, brownish (2.5Y4/4 or 5/4). Friable breaking into subangular blocks.
Upper Subsoil	Clay start depth varies from 20 to 60cm, overlain by silty clay loam or silty clay - grey (2.5Y5/3) to yellowish-brown (5/6) with common iron or manganese mottles. Very slightly calcareous.
Lower Subsoil	Firm clay, light (greenish) grey (10-7.5GY-7/1) with many ochreous and some manganese. Slowly permeable, passes to very dense mudstone within 1m. Locally calcareous.
Limitations	WC III (locally IV) due to slowly permeable subsoil within 45cm. Bean growth seems restricted by compaction; patches of weed or no establishment. Heavier topsoil sets Grade at 3b (wetness). See Appendix 3 pit C.

3.9 The main limitations to agricultural land quality at the site are soil wetness, droughtiness and flooding/groundwater.

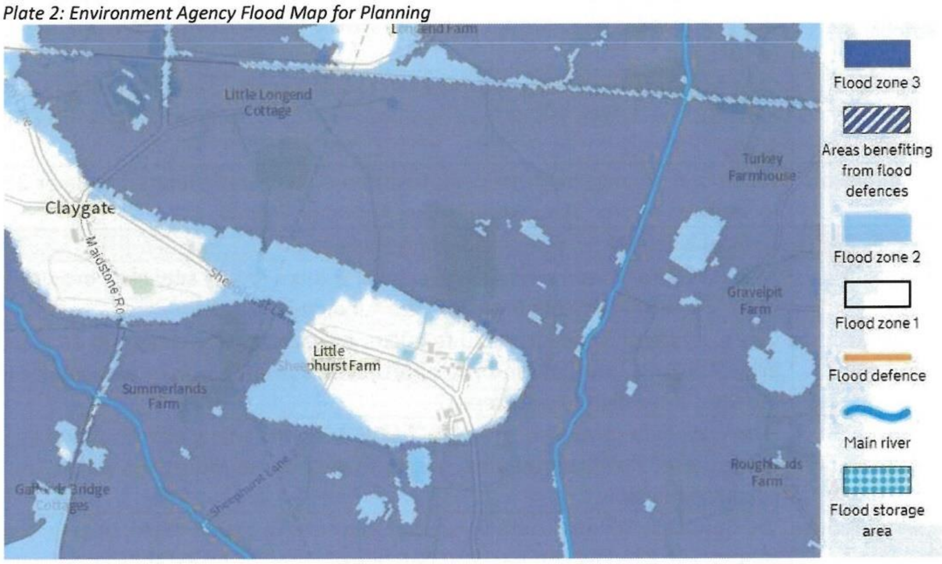
3.10 **Wetness/Workability.** Many of the River Terrace and Alluvial soils are characterised by thin clayey or compact layers in the upper subsoil overlying looser material below 50cm (see Appendix 3 Pits A, E and F). These compact layers can be remedied by subsoiling and are not a grade limitation unless they are at least 15cm thick. Profiles classified as Subgrade 3b either have silty clay topsoil or are WC III with heavy silty clay loam topsoil. Profiles with medium clay loam topsoils are limited to Grade 2 or 3a depending on WC.

3.11 The Weald clay subsoils are slowly permeable, although the presence of traces of carbonate in the clay upper subsoil assist soil structure (Appendix III, pit C) but cannot rate higher than WC III.

3.12 **Droughtiness.** Most soils have good water reserves for deep rooted crops, and are limited to Grade 2 (3a on some deep clay profiles). Other profiles are downgraded to Subgrade 3a because of limited water supply to 70cm for shallower rooted crops (Appendix 2).

3.13 **Flood risk.** As shown in Plate 2, most of the site is shown as being at moderate risk of flooding (Flood Zone 3), with the main river running along the eastern edge of the site. Groundwater was not encountered in any of the profiles. The high concentrations of manganese fragments in the lower subsoil indicate fluctuating groundwater but much is relic historical, since most fields now have functioning deep ditches to lower the water table.

Plate 2: Environment Agency Flood Map for Planning

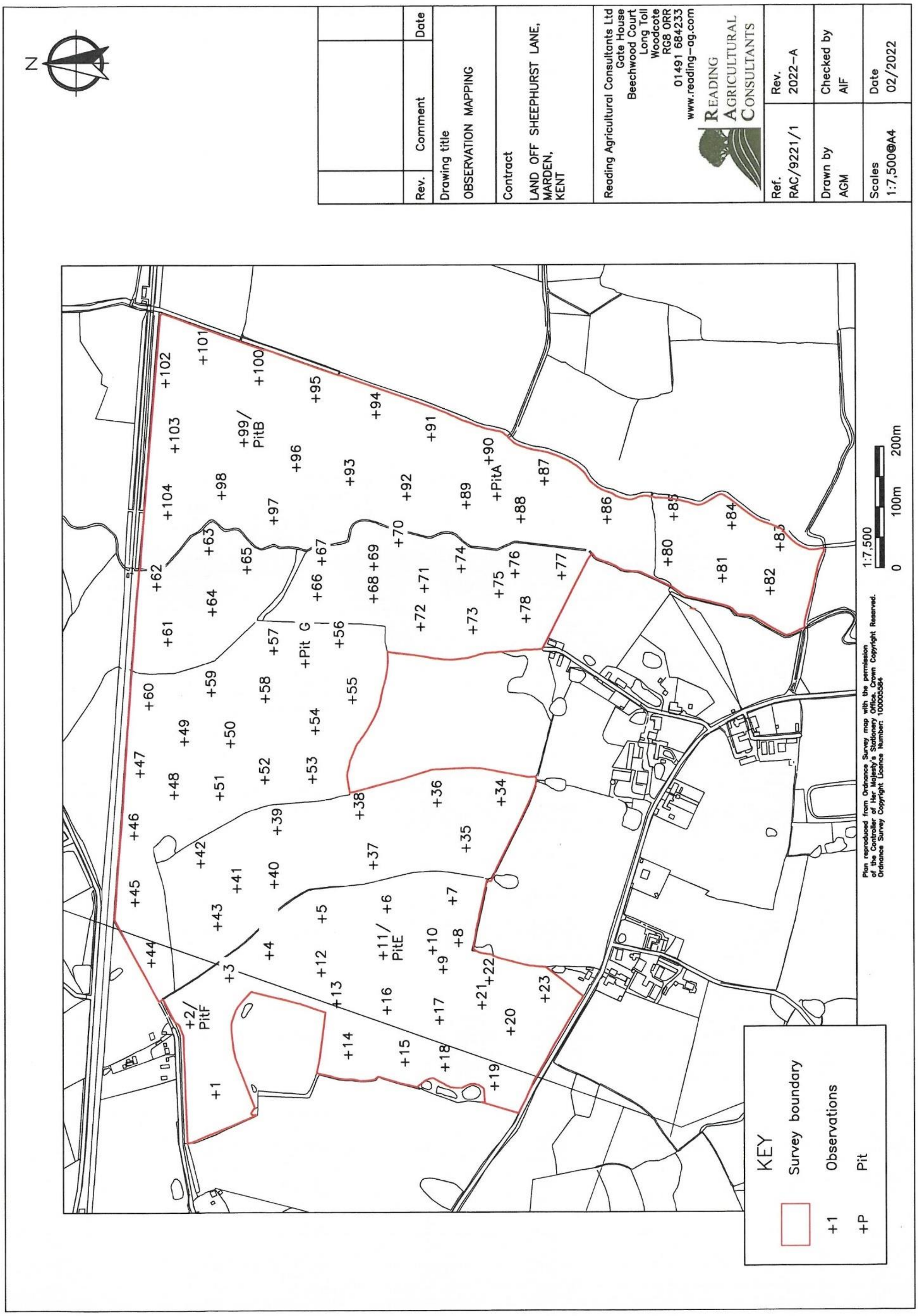


3.14 According to one local source, the land is usually dry but floods seriously in about one year in twenty. Unless this happens in summer, Grade cannot be lowered to less than 2 on flood risk. There were however some areas of poor crop establishment noted during the survey which correspond with water collecting hollows, and which are downgraded to Subgrade 3b. Some problem patches in the south-eastern field (shown as Flood Zone 2) might be related to spring-line effects as well as from the restricted permeability of the Weald clay.

3.15 The areas of each ALC grade are given in Table 3 and their distribution is shown in Figure RAC/9221/2.

Table 3: ALC areas

Grade	Description	Area (ha)	%
Grade 2	Very good quality	6.9	9
Subgrade 3a	Good quality	28.2	38
Subgrade 3b	Moderate quality	39.4	53
Total		74.5	100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Date
Drawing title
OBSERVATION MAPPING
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Reading Agricultural Consultants Ltd
Gate House
Beechwood Court
Long Toll
Woodcote
RG8 0RR
01491 684233
www.reading-ag.com
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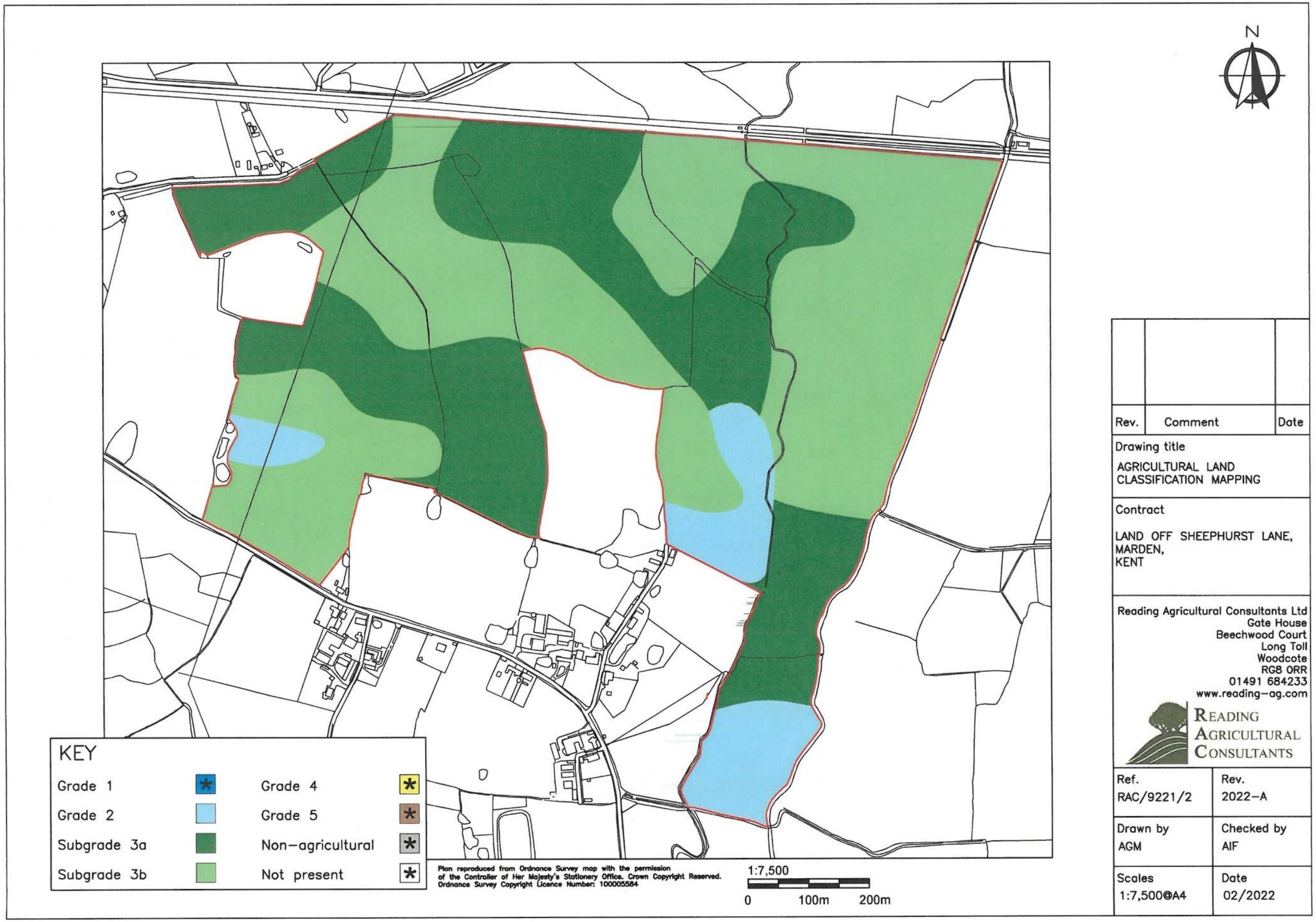
Plan reproduced from Ordnance Survey map with the permission of the Controller of Her Majesty's Stationery Office. Crown Copyright Reserved. Ordnance Survey Copyright Licence Number: 100005584
KEY
Survey boundary
+1 Observations
+P Pit


N
KEY
Grade 1
Grade 2
Subgrade 3a
Subgrade 3b
Grade 4
Grade 5
Non-agricultural
Not present
Plan reproduced from Ordnance Survey map with the permission of the Controller of Her Majesty's Stationery Office. Crown Copyright Reserved. Ordnance Survey Copyright Licence Number: 100005584
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APPENDIX KCC6

BSS Publication Soil Carbon (2022)

SCIENCE NOTE: SOIL CARBON

BRITISH SOCIETY OF SOIL SCIENCE

Highlights

- There is an urgent need to reduce atmospheric carbon dioxide (CO_2) concentrations.
- Supporting natural and agricultural systems to sequester carbon (C) can help achieve this.
- Many soils have the capacity to sequester C from the atmosphere, however the process is slow, easily-reversible and time-limited.
- The greatest and most rapid soil C gains can be achieved through land use change (e.g. conversion from arable land to grassland or woodland), but this can have implications for food production and the displacement or exporting of emissions.
- Increasing soil organic C contents through sustainable soil management (SSM) practices can improve soil health, the efficiency of food production and the delivery of multiple public goods and services.
- Where financial incentives are developed to encourage SSM practices and sequester C it is essential that funders provide ongoing support to these schemes.
- Given the uncertainties around the amount of additional C that can be sequestered in future, and the ease with which C gains can be lost, it is essential that the carbon stores in existing permanent grasslands, moorlands, peatlands, wetlands and woodlands are protected.

Introduction

Recent reports from the Intergovernmental Panel on Climate Change (IPCC) highlight how human activity is changing the climate in unprecedented and sometimes irreversible ways.

The reports make it clear that action to tackle climate change is an urgent priority. The 26th United Nations Climate Change conference (COP26) is due to take place in Glasgow in November 2021 and is seen as critical for establishing a robust path to future zero or negative emissions of greenhouse gases (GHG's) at a global scale. There is an urgent need to reduce fossil fuel emissions to near zero, while supporting natural systems to sequester and store carbon (C). Soils contain more C than in the atmosphere and vegetation combined and are therefore an essential *carbon store*. Under certain conditions with careful management they can act as an important *carbon sink*.

Increasing the amount of C stored in soil is beneficial from a climate change mitigation perspective, but how much C can be stored in this way?

This science note aims to:

- Set out the importance of C in soils, how it behaves, and the role it plays in supporting soil functions, delivering vital public goods and services, and helping societies adapt to and reduce the rate of climate change.
- Raise awareness of the main issues surrounding soil C and the actions that governments, communities and individuals can take.

Carbon sequestration
A net transfer of carbon (C) from the atmosphere to land (either into soil or vegetation).

Carbon store
A medium that stores C. Over a given period of time, the amount of C in the store may be increasing, decreasing or static.

Carbon sink
Any reservoir or medium that over a given period of time accumulates and stores more C than it loses.

Carbon source
Any reservoir or medium that over a given period of time loses more C than it accumulates.

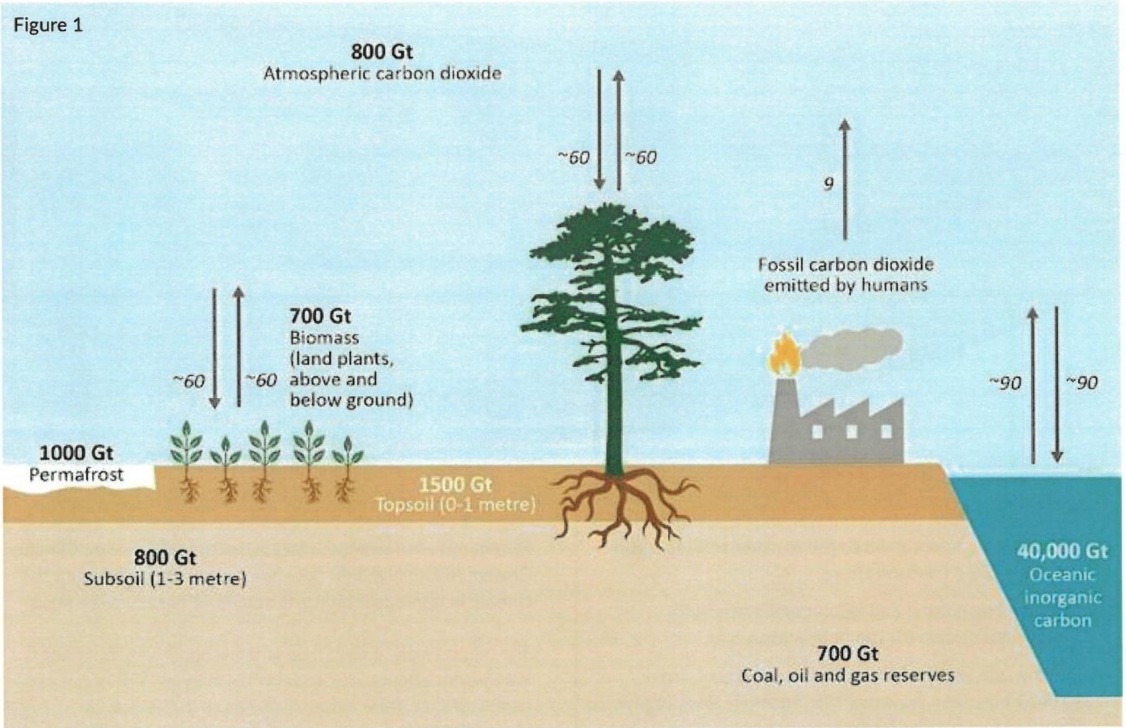

Figure 1: Carbon stocks and flows on land and in the oceans (adapted from Jenkinson, 2010 [1]). The numbers in bold are stocks in Gigatonnes (Gt) C: those in italics are flows in Gt C per year. Topsoil and subsoil stocks exclude peatlands.

What is soil carbon?

C is the fourth most abundant element in the universe by mass after hydrogen, helium and oxygen, and is the primary basis of life on Earth.

The ability of C to form many bonds allows it to form large complex molecules that attach to other elements that are essential to life, such as nitrogen (N), phosphorus (P) and sulphur (S). These bonds also trap energy as a source of fuel for microorganisms.

The soil C stock is around three times that of the atmosphere, at around 2,300 Gt (2.3 trillion tonnes) to three metres depth and 1,500 Gt in the top metre

When plants, animals and microorganisms die and decompose, their remains form organic matter of which about half is C, and on land this combines with weathered minerals from rock (inorganic material) to form soil.

After the world's oceans, soil is the world's largest active C store, holding 80% of terrestrial C, which is almost three times the amount held in the world's atmosphere [2] [Figure 1].

Carbon concentrations are usually smaller in sandy (light) soils and larger in clay (heavy) soils.

Soil organic carbon (SOC) content varies enormously from less than 1% in desert soils to over 50% in peats but is typically less than 5% in most agricultural soils [3].

Deforestation and cultivation can reduce SOC by exposing it to the process of oxidation and conversion to CO_2 which is emitted into the atmosphere. Within soil ecosystems there is a constant exchange of C between SOC and the atmosphere, and these interactions and transformations are part of the global C cycle (Figure 2, page 3).

C is found in soils in two forms:

- **Soil organic carbon (SOC)** – the living and dead components of organisms, including fine plant roots, root exudates, fungi, microbes and decomposing organic matter from plant litter or animal products such as manure.

- **Soil inorganic carbon (SIC)** – chemical compounds such as calcite or chalk (calcium carbonate: $CaCO_3$) [4]. SIC is generally more stable than SOC and accounts for approximately 38% of the total soil C pool. It is much more abundant in the low rainfall regions than in moist, temperate regions of the globe. SIC can also be added to soils in the form of amendments such as rock dust and could be a means of storing more SIC in soils. However, the full cycle and cost-benefit analysis of this emerging technique needs further consideration.

SIC is predominantly controlled by the weathering of C-based rock minerals (mostly underlying chalk and limestone in the UK) and it can essentially be considered to be a fixed constant for most temperate zone soils, notwithstanding the application of lime and other carbonate-containing mineral amendments in agriculture. For this reason, it is SOC that is the more dynamic fraction, being more responsive to management, and it is SOC that is the focus of this scientific note.

Soil organic carbon (SOC) levels can be increased (or decreased) through changes in management, although it normally takes years to decades to bring about measurable change. Where SOC stocks are currently large e.g. under old grassland or forest, it is important to keep them and not lose them through changing land use. Long-term historical loss of SOC, (particularly in arable soils) offers a potential route for future C storage increases.

Soil carbon stocks and flows

Carbon dioxide (CO_2) in the air is absorbed by plants through photosynthesis, creating biomass that is eventually deposited on or in soil as wood, leaf litter, root exudates and root material [Figure 1, page 2]. In well-aerated soils, most of the C in this plant debris is converted back to CO_2 by the activities of soil organisms (fungi, bacteria, etc.) through soil respiration, but a fraction is retained in soil and becomes stabilised to varying degrees. In temperate climates about one third of plant C entering soil is still present after one year. Integrated with the cycling of C is the cycling of important plant nutrients, which enhances soil fertility. As organic matter enters the soil, the soil organisms process it to mineralise the key nutrients into forms that are available to plants [5].

Soil conditions vary and in more extreme environments (such as very acidic, dry or wet) soil C turnover is reduced. For example, in waterlogged soils, with very low oxygen levels, decomposition is slow to non-existent and peat forms along with other 'saturated soil' (anaerobic) decomposition products, including methane (CH_4), an important GHG [2]. Where these conditions are maintained for centuries, such as on upland bogs and lowland fens, peat accumulates over time. However, if these peats are drained, allowing air to enter, microbial respiration is reactivated and the peat C is emitted as CO_2 at rates in excess of 30 t CO_2/ha/yr [6], although it will take many decades to lose all this stored C.

Plants also respire all the time (Figure 2) and use the sugar produced through photosynthesis to drive their metabolism in

Figure 2

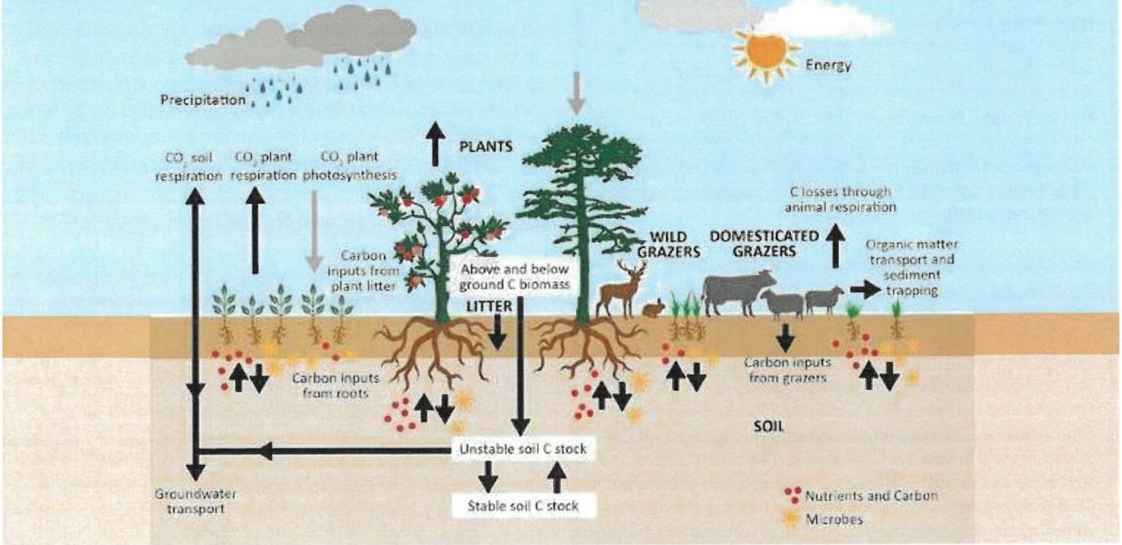

Figure 2: A simplified representation of the carbon cycle in terrestrial ecosystems (adapted from Garnett *et al.*, 2017 [7]).

a process known as plant respiration. In stable ecosystems, and in many agricultural systems, which have not changed for decades, photosynthesis and plant/microbial respiration are in balance, with the overall effect on atmospheric CO_2 being zero.

However within these systems, in addition to respiration, C is removed through harvested crops and livestock products, and also through animal respiration and fermentation from ruminating cattle, sheep, goats and domesticated deer; and in addition to photosynthesis, C is returned to the land as crop residues, livestock manure (Figure 1), human sewage and food waste. Organic C can also be added to soils as biochar, a stable form of C that is a category of charcoal (See Biochar box). If the rate of C input is greater than the rate of decomposition, then the amount of C in the soil increases. The opposite is true where the rate of decomposition exceeds C input [5].

Humans have therefore had an important influence on the C cycle through the burning of fossil fuels (Figure 1), breeding of domesticated livestock on a large scale and replacing natural ecosystems with agricultural and urban land. All these activities have altered the balance of the *natural* C cycle to such an extent that in many agricultural systems the amount of plant and microbial respiration (due to a combination of bare soils and cultivation) exceeds the amount of photosynthesis, resulting in a gradual depletion of SOC. However, this depletion can be reversed through land use change and sustainable soil management (SSM) practices [8].

Biochar

Biochar is the organic and inorganic C remains of organic material that has been heated in the absence of air (oxygen) to produce a form of charcoal. This heating or *pyrolysis* can prevent the C from degrading and returning to the air [9]. Biochar can also support soil fertility through nutrient and water storage and release, particularly in degraded soils. It can also stabilise heavy metals and promote pollutant immobilization. However, for the UK, the efficacy and GHG removal potential of biochar is limited by domestic biomass resource and prohibitively high costs, resulting in an estimated potential for biochar of no more than 6 to 41 Mt CO_2/year [10].

As biochar composition varies depending on source material, processing, local climate and soil type, the timeframe over which biochar-C remains sequestered in the soil is uncertain. There is also a lack of long-term data, e.g. biochar crop yield response field experiments provide only four to five years of data, and glasshouse experiments are necessarily short-term [11]. Therefore, it is suggested that biochar should meet quality standards, be closely monitored and only used in specific targeted circumstances that maximise its benefits [9]. Although the use of biochar should be tightly regulated, where it is applied with care it has the potential to increase long-term soil C, at a greater rate than any other treatment or management technique [12].

Soil carbon functions [13]

There are many reasons why we should be concerned about protecting or increasing the stock of C within soils [14, 15]. SOC has a profound influence on soil properties and functions that affect the production of food and fibre. It also impacts on the functions that soils perform for the wider environment such as regulating the flow and quality of water, providing clean air, filtering pollutants and contaminants, and supporting biodiversity. All functions which are often termed 'soil ecosystem services' (SES) are reliant on the turnover of SOC and are closely related to 'soil health' [15,16,17].

Soil organic C is an essential component of soil structure, function and soil life

SOC is the energy supply that enables soil organisms to carry out their functions in a healthy soil. Together with soil microorganisms, SOC is a key factor in the formation and stabilisation of soil structure – the system of aggregates (units of sand, silt and clay particles bound together) and the surrounding pore network (containing air and water) [18]. SOC can interact with soil particles (notably clay) to form small aggregates through various chemical and biological processes. The processing by soil microorganisms of organic matter that enters the soil from leaf litter or from roots produces substances which act as a glue (glomalin) to combine smaller aggregates into larger aggregates, making the aggregates more stable and resistant to external forces such as raindrop impact and cultivation [19]. The greater resilience of soil aggregates also stabilises the soil pore network, allowing the soil to carry out its functions of retaining water for plants, transmitting water down to the groundwater and, in the topsoil, allowing plant roots to grow without restriction and to access nutrients.

In general therefore, a soil with a greater SOC content has a more stable structure, is less prone to runoff and erosion, has greater water infiltration and retention, increased biological activity and improved nutrient supply compared to the same soil with a smaller SOC content [20, 21]. Even small increases in SOC can markedly influence and improve these properties [22].

Soil carbon stores and fluxes

SOC is a key component of the global C budget and changes in stocks have implications for the mitigation or intensification of climate change. The largest stocks of soil C are found in non-agricultural soils with a peaty surface horizon (e.g. semi-natural grasslands, moorlands and wetlands), woodlands, peatlands, and uncultivated long-term agricultural permanent pasture, where it is important to protect the existing C stores [23, 24, 25]. Soil C sequestration represents an important mitigation route for climate change and is achieved largely by stabilisation rather than turnover of SOC.

Although soils used for arable agriculture (annually cultivated) typically have smaller SOC contents than grassland or woodland soils, they are potentially more amenable to alteration through direct management interventions. Soil C stocks can be increased by either increasing inputs (e.g. crop residues, cover crops, use of organic materials, inclusion of grass leys in arable rotations) or decreasing losses (i.e. reducing oxidative losses to CO_2, or particulate and dissolved organic content), via improved management such as reduced intensity tillage [26]. Significant long-term land use change (e.g. conversion of arable land to grassland or woodland) has by far the biggest impact on SOC, but is unrealistic on a large scale because of the continued need to meet food security challenges.

More practical approaches could be the inclusion of grass leys into arable rotations (i.e. arable soils being under grass for several years in a crop rotation). This may result in a more sustainable system with healthier soil, although the cycling of C will result in some GHG emissions, and the whole rotation crop productivity is decreased since there is no human-edible crop during ley years. Integrating livestock may displace some human edible crop production, emit more CH_4 (if ruminant livestock numbers are not reduced elsewhere), and the change in soil C stocks is small compared with that of land use change.

Since changes to soil C occur over periods of many years, the financial benefits of soil C sequestration are normally based on modelled future soil C levels. Such models need to be relevant to individual soil types, land use and climate, and need to be accurately baselined through field measurements.

Nevertheless, relatively small changes in C stock per unit area in arable agricultural soils may translate into substantial stock increases at the national or regional scale [27, 28]. There has been much discussion of the possibility of mitigating climate change through soil C sequestration [27]. However, changes in SOC are generally slow to occur and, because of the large background C in soils and the inherent variation, it is difficult to measure accurately.

Moreover, the process of soil C sequestration is often misunderstood, and can lead to an overestimation of the climate change mitigation achievable by using this route [28]. This is primarily because the quantity of C that can be stored in any soil is finite. After a positive change in management practice, soil C levels increase (or decrease) towards an equilibrium value (after 20-100 years or more) that is characteristic of the 'new' land use, management system and climate [21]. The relatively large annual rate of soil C accumulation in the early years after a major change in land use or management (such as a change from a conventional cultivated arable rotation to a reduced tillage system incorporating grass leys and cover cropping) cannot be maintained indefinitely and the annual rate of increase will decline (eventually to zero) as the soil approaches its new equilibrium. The use of organic amendments in arable agriculture, such as composts and manures, is a practice that can increase SOC, but the supply is finite and there are costs incurred with such practices. It is therefore unlikely that the initial rate of increase in soil C following a change in land use /management practice will be sustained over the longer term (>20 years), as the new equilibrium level is reached.

When increased over time through altered management, soil C concentrations will reach an equilibrium state beyond which, no further increases are (naturally) possible.

Beneficial soil management approaches need to be continued beyond the equilibrium point to prevent returns to prior low C status.

In addition, C sequestration is reversible. Maintaining a soil at an increased soil C level, due to a change in management practice, is dependent on continuing that practice indefinitely. Indeed, soil C is lost more rapidly than it accumulates [29]. Also, to increase soil C levels, inputs of other elements such as nitrogen (N) and phosphorus (P) are needed. [30] The soil C, N and P cycles are intimately linked, and increasing soil C may affect the release of diffuse water pollutants (nitrate-NO_3 & phosphate-P) and GHGs considerably more potent than CO_2 (e.g. nitrous oxide (N_2O) & CH_4).

In other words, there is a risk of 'pollution swapping' where the reduction of one form of pollution increases another. Land use changes such as reafforestation and wetland creation may also result in deforestation and cultivation elsewhere to grow the food that is not produced in the C sequestration project (i.e. displacement) [31].

Despite these risks and limitations, there is scope for soil C sequestration to contribute to climate change mitigation, particularly on low C, degraded landscapes. It is equally important that this C sequestration is allied with retention of existing SOC stocks in non-agricultural and long-term permanent pasture soils. Maintaining or enhancing SOC levels can deliver a range of benefits not only for climate change mitigation, but also for soil quality and functioning which can make soils more resilient to the impacts of climate change (e.g. ability to cope with extreme events such as droughts and floods) and other global change factors [32].

Measurement, Monitoring, Reporting, Verification (MRV) and Valuing

Sequestering additional C in agricultural soils is attracting interest from governments and industry as a way to meet climate change objectives and is leading to the development of schemes to pay farmers to adopt SSM practices. Such soil-focussed schemes do not yet exist in the UK, but equivalents have been running in Australia and Canada for a number of years [33] and the European Commission's Carbon Farming Initiative is due in 2021. The Australian Emission Reductions Fund (ERF) and Carbon Farming Initiative encourage the adoption of a number of land management strategies that result in either the reduction of GHG emissions or the sequestration of atmospheric CO_2, while the Conservation Cropping Protocol in Canada provides payment for no-till cropping [34].

> Any financial mechanism based on soil C status needs to include mechanisms to accommodate situations where soil C:
>
> - has declined over an agreed sequestration period
> - has increased (relative to other soils of a similar type) prior to an agreed sequestration period.

Setting up robust monitoring, reporting and verification (MRV) platforms for soil C is very challenging, due not just to variations in how changes in soil C are influenced by climate, land use and management in different agro-climatic regions, but also because it can be difficult to determine the baseline soil C content against which to judge (and pay for) the success of any sequestration initiatives [35]. The potential for future land management changes to cause captured C to be re-released from soils also means that monitoring has to be robust for the lifetime of any payment scheme.

Existing MRV protocols for soil C credits take different approaches to quantifying soil C and net removals of GHGs from the atmosphere. Some rely on soil sampling, some combine sampling with process-based modelling, while others rely on combinations of modelling and remote sensing [35]. Differences in the way protocols and C markets estimate sequestration make it difficult to be confident that climate benefits have actually been achieved – but the costs associated with direct measurement of soil C make it impractical as a long-term monitoring option [2], meaning that models and remote sensing become essential once a ground-truthed soil C baseline has been established. Ground truthing needs to take account of the high degree of variability between soil C contents even where soils are apparently similar across a field. An alternative is to simply link specific management practices to mean C sequestration potential within a set of given contexts.

Soil C sequestration provides a useful tool in global efforts to tackle GHG emissions, but the slow rate of change, the relatively small amounts that can be sequestered (e.g., in 2010 it was calculated that even the most extreme land use change scenarios in Great Britain would account for only c. 2% of national GHG emissions [36]), and the ease of reversibility in soil C gains present significant challenges with respect to measurement, monitoring and verification [5]. Stakeholders must be aware that a focus on soil C can have unintended consequences and should not be perceived as a 'quick fix'.

Conclusions and recommendations

Climate Change is arguably the greatest challenge facing humanity and efforts are underway globally to reduce GHG emissions and to capture those that continue to be emitted.

The counterbalancing need, on the one hand, to remove C from the atmosphere and, on the other, to add C to soils, presents an obvious confluence. Soils are a significant reservoir of C, but land use changes over centuries have resulted in a proportion of that C being lost from many soils. Although present in both organic and inorganic forms, it is SOC and (more specifically) soil organic matter that is critical to the functioning and resilience of soils in countries such as the UK. This is why addressing historic C losses provides clear potential for improving soil quality and for future C sequestration in soils, which is leading to the development of monetised soil C sequestration schemes that can be built into governmental or corporate strategies to offset residual GHG emissions.

Increasing the SOC of degraded soils can significantly improve productivity and resilience, and SSM techniques such as reduced intensity tillage, residue management to maintain ground cover, the use of cover crops, and the application of bulky organic manures (e.g. compost) are commonly used to achieve this. Changing SOC concentrations with such techniques can however take decades, and gains can be rapidly reversed in the event of further land management changes. Further, increases in soil C will not continue indefinitely; rather C concentrations will reach new equilibria, which can themselves only be maintained by continuation of the favourable management practices. Equilibrium concentrations of C will vary depending on soil type, land use and climatic conditions. It is possible that in some circumstances the natural SOC store can be augmented to some extent through use of basalt minerals or biochar, which offer potential for longer term inorganic or organic C storage - but the whole life cycle C costs of such techniques need to be considered with care before genuine sequestration benefit can be claimed. The source and chemical characteristics of biochars and rock dusts can also be problematic from both regulatory and environmental perspectives.

In the UK context, it is essential that historic SOC declines are addressed if soils are to function effectively, improving their resilience to increased temperatures, increased intensity of rainfall events and other inevitable effects of climate change. However, this essential requirement creates significant potential for abuse at a time when governments, corporations and individuals are increasingly keen to offset their C emissions through sequestration initiatives.

Although this Science Note is based on a UK perspective, we recognise that the same issues apply internationally and there is a need for action on a global scale.

Based on the available scientific evidence, we recommend that:

- The C stores in existing permanent grasslands, moorlands, peatlands, wetlands and woodlands are protected.
- SSM practices are more widely adopted to increase SOC, to help mitigate existing GHG emissions, to improve soil health and resilience, and to protect and enhance the multiple public goods and services provided by soil.
- Where financial incentives are developed to encourage SSM practices it is essential that funders provide ongoing support to these schemes. This recommendation applies equally to any scheme claiming C sequestration in soils.
- Soil C concentrations should be periodically monitored. While modelling can be used to estimate future C stocks in specific soils, it is essential that these estimates are validated through soil testing at a network of representative field sites.
- Sequestering C in soils and vegetation, although important, must not distract from the urgent need to reduce CO2 emissions from the burning of fossil fuels. Failure to address the latter will render the former irrelevant.
- Attempts to overcome natural soil C equilibria through application of materials such as rock dust or biochar must consider the whole life C costs of such practices as well as ensuring that they do not impact negatively on soil quality through pH change, chemical contamination or other undesirable characteristics.

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Bibliography

[1] Jenkinson, D. S. (2010) *Climate change - a brief introduction for scientists and engineers or anyone else who has to do something about it*. Rothamsted Research. https://repository.rothamsted.ac.uk/item/8v478/climate-change-a-brief-introduction-for-scientists-and-engineers-or-anyone-else-who-has-to-do-something-about-it

[2] Keenor, S. G *et al.*, (2021) Evidence synthesis: Capturing a soil carbon economy. *Royal Society Open Science*, 8(4) https://doi.org/10.1098/rsos.202305

[3] IUSS Working Group WRB (2015) *World Reference Base for Soil Resources 2014 (update 2015) International soil classification system for naming soils and creating legends for soil maps.* World Soil Resources Reports No. 106. FAO, Rome

[4] World Bank. (2021) *Soil Organic Carbon MRV Sourcebook for Agricultural Landscapes* World Bank, Washington, DC http://hdl.handle.net/10986/35923

[5] Yeluripati, J *et al.*, (2018) *Payment for carbon sequestration in soils: A scoping study* ResearchGate https://doi.org/10.13140/RG.2.2.26883.55847

[6] Evans C. *et al.*, (2016) *Lowland peat systems in England and Wales - evaluating greenhouse gas fluxes and carbon balances* (DEFRA Project SP1210) http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=17584

[7] Garnett, T. *et al.*, (2017) *Grazed and Confused? Ruminating on cattle, grazing systems, methane, nitrous oxide, the soil carbon sequestration question – and what it all means for greenhouse gas emissions FCRN*, University of Oxford https://www.oxfordmartin.ox.ac.uk/downloads/reports/fcrn_gnc_report.pdf

[8] UN FAO (2017) *Voluntary Guidelines for Sustainable Soil Management* http://www.fao.org/3/bl813e/bl813e.pdf

[9] Sohi, S (2012) Carbon Storage with Benefits. *Science* 338 https://10.1126/science.1225987

[10] Royal Society (2018) *Greenhouse GAS Removals* https://royalsociety.org/-/media/policy/projects/greenhouse-gas-removal/royal-society-greenhouse-gas-removal-report-2018.pdf

[11] Abiven, S. *et al.*, (2014) Biochar by design. *Nature Geoscience:* Volume 7 May 2014

[12] Joseph, S. *et al.*, (2021) How biochar works, and when it doesn't: A review of mechanisms controlling soil and plant responses to biochar *GCB-Bioenergy* In press. https://doi.org/10.1111/gcbb.12885

[13] Keesstra, S. D. *et al.*, (2016) The significance of soils and soil science towards realization of the United Nations Sustainable Development Goals *SOIL* 2: 2 111-128

[14] Powlson, D.S. *et al.*, (2012) The Potential to increase Soil Carbon Stocks through Reduced Tillage or Organic Material Additions in England and Wales: a Case Study *Agriculture Ecosystems Environment* 146(1): 23-33

[15] Lal, R. (2016) Soil health and carbon management *Food and Energy Security* 5(4):212-222

[16] Janzen, H.H. (2006) The soil carbon dilemma: Shall we hoard it or use it? *Soil Biology and Biochemistry* 38(3):419-424

[17] Smith, P. *et al.*, (2021) The role of soils in delivering Nature's Contributions to People. *Philosophical Transactions of the Royal Society, B 376*: 20200169. https://doi: 10.1098/rtsb-2020-0169

[18] Tisdall, J.M. & Oades, J.M. (1982) Organic matter and water-stable aggregates in soils. *Journal of Soil Science* 33: 141-163. https://doi: 10.1111/j.1365-2389.1982.tb01755.x

[19] Redmile-Gordon, M. *et al.*, (2020) Soil organic carbon, extracellular polymeric substances (EPS), and soil structural stability as affected by previous and current land-use. *Geoderma* 363:114143. https://doi.org/10.1016/j.geoderma.2019.114143

[20] Bhogal, A. *et al.*, (2018) Improvements in the Quality of Agricultural Soils Following Organic Matter Additions Depend on Both the Quantity and Quality of the Materials Applied. *Frontiers in Sustainable Food Systems, Waste Management in Agroecosystems* 19 April 2018 https://doi.org/10.3389/fsufs.2018.00009

[21] Johnston, A. E. *et al.*, (2009) Soil organic matter: its importance in sustainable agriculture and carbon dioxide fluxes *Advances in Agronomy* 101:1-57

[22] Watts, C. W. *et al.*, (2006) The role of clay, organic carbon and long-term management on mouldboard plough draught measured on the Broadbalk wheat experiment at Rothamsted *Soil Use and Management* 22(4):334-341

[23] Jobbágy, E.G., Jackson, R.B. (2000) The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecological Applications*, 10:423-436. https://doi: 10.2307/2641104

[24] Gregory, A.S. *et al.*, (2014) An assessment of subsoil organic carbon stocks in England and Wales. *Soil Use and Management*, 30:10-22. https://doi: 10.1111/sum.12085

[25] Chapman, S. J. *et al.*, (2013) Comparison of soil carbon stocks in Scottish soils between 1978 and 2009. *European Journal of Soil Science*, 64: 455-465. https://doi: 10.1111/ejss.12041

[26] Poulton, P. R. *et al.*, (2018) Major limitations to achieving "4 per 1000" increases in soil organic carbon stock in temperate regions: Evidence from long-term experiments at Rothamsted Research, United Kingdom *Global Change Biology* 24(6):2563–2584

[27] Smith, P. *et al.*, (2008) Greenhouse gas mitigation in agriculture *Philosophical Transactions of the Royal Society B: Biological Sciences* 363(1492): 789-813

[28] Smith, P. *et al.*, (2000) Meeting Europe's climate change commitments: quantitative estimates of the potential for carbon mitigation by agriculture *Global Change Biology* 6(5):525-539

[29] Powlson, D. S. *et al.*, (2011) Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false *European Journal of Soil Science* 62(1):42-55

[30] Davies C. A. *et al.*, (2021) The importance of nitrogen for net carbon sequestration when considering natural climate solutions *Global Change Biology* 27(2): 218-219. https://doi: 10.1111/gcb.15381. Epub 2020 Oct 30. PMID: 33124108

[31] Smith, P. (2012) Soils and climate change. *Current Opinion in Environmental Sustainability* 4: 539–544. https://doi: 10.1016/j.cosust.2012.06.005

[32] Rillig M. C. *et al.*, (2019) The role of multiple global change factors in driving soil functions and microbial biodiversity. *Science*. 2019 Nov 15;366(6467):886-890. https://doi: 10.1126/science.aay2832. PMID: 31727838; PMCID: PMC6941939.

[33] Environmental Defense Fund, & Woodwell Climate Research Center (2021) *Agricultural Soil Carbon Credits* https://www.edf.org/sites/default/files/content/agricultural-soil-carbon-credits-protocol-synthesis.pdf

[34] Paustian, K. *et al.*, (2019) Quantifying carbon for agricultural soil management: from the current status toward a global soil information system. *Carbon Management* 10(6):567-587 https://doi.org/10.1080/17583004.2019.1633231

[35] Smith, P. *et al.*, (2020) How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal. *Global Change Biology* 26(1): 219–241 https://doi.org/10.1111/GCB.14815

[36] Smith, P. *et al.*, (2010) Consequences of feasible future agricultural land-use change on soil organic carbon stocks and greenhouse gas emissions in Great Britain *Soil Use and Management* 26:4 381-398 https://doi.org/10.1111/j.1475-2743.2010.00283.x

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