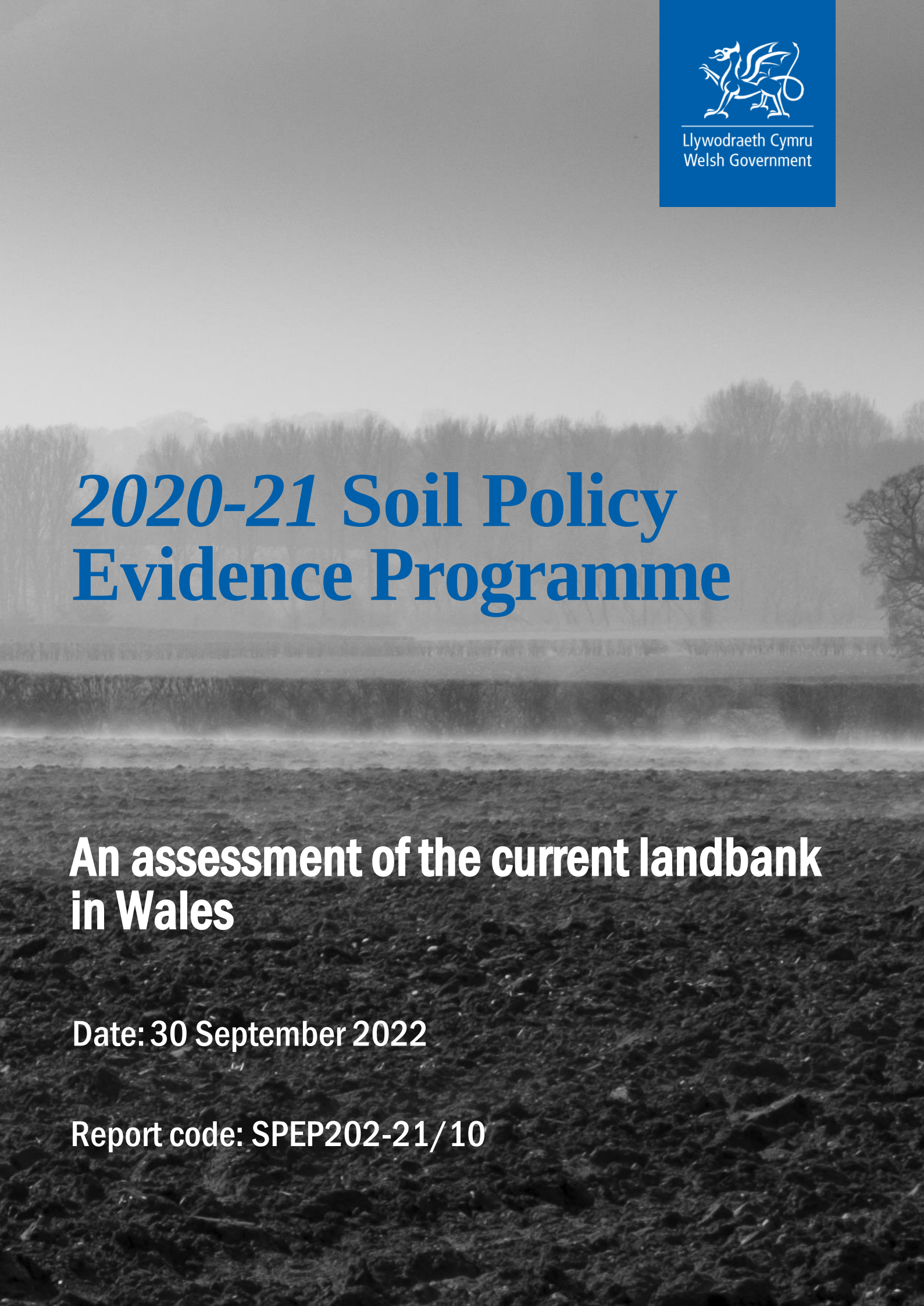


Llywodraeth Cymru
Welsh Government

2020-21 Soil Policy Evidence Programme

An assessment of the current landbank in Wales

Date: 30 September 2022

Report code: SPEP202-21/10

ADAS GENERAL NOTES

Project No. 1021874

Title: An assessment of the current landbank in Wales

Client: Welsh Government and Natural Resources Wales

Date: 30 September 2022

Authors: Dr Alison Rollett, ADAS Gleadthorpe, Netherfield Lane, Meden Vale, Nottinghamshire, NG20 9PD and John Williams, ADAS Boxworth, Battlegate Road, Boxworth, Cambridgeshire, CB23 4NN.

Status: Final

Author	Alison Rollett	**Technical reviewer**	John Williams
Signature		Signature	
Date:	30 September 2022	Date:	29 September 2022

Project manager	Alison Rollett
Signature	
Date:	30 September 2022

Contents

Executive Summary

Objective

- The overall objective of this project was to use currently available evidence to investigate the distribution and size of the landbank available for organic materials (as defined in the Work Package 1 report) in Wales using the ALOWANCE (Agricultural Land: A National Capacity Estimator) tool (Nicholson *et al*., 2012).

Background

- An estimated 10 million tonnes of organic materials are applied to agricultural land in Wales each year. Organic materials provide major plant nutrients (nitrogen-N, phosphorus-P, potassium-K, sulphur-S, magnesium-Mg) and trace elements (e.g., copper-Cu, zinc-Zn, manganese-Mn, boron-B). Accounting for manure nutrients in nutrient management plans will reduce fertiliser costs and limit nitrate and phosphorus losses to water, and ammonia and nitrous oxide emissions to air.
- New regulatory controls on nitrogen losses to water in Wales, The Water Resources (Control of Agricultural Pollution) (Wales) Regulations 2021 (WSI, 2021) came into force on 1 April 2022. The regulations apply to the whole of Wales (and to the application of all organic materials) and replace the previous Nitrate Vulnerable Zones (NVZs), which only covered 2.4% of Wales. The new regulations embed in law recommended good practice by setting rules for certain farming practices including limits on nitrogen loading from livestock manures, nutrient management planning and the application of organic materials.
- In comparison, there are no specific regulatory limits on the application of P to agricultural land, although Environmental Permit Regulations (EPR) require that the organic material applications result in benefit to agriculture or ecological improvement. EPR guidance states that "If phosphate is to be applied at index 3 or above, the operator should: explain why the increased levels are appropriate for the receiving land and, address the increased risks from the application in the risk assessment within the benefit statement" (NRW, 2017).

ALOWANCE model

- ALOWANCE estimates the agricultural landbank available for organic materials from farm and non-farm sources, based on nitrogen (N) loading rates, the physical and soil constraints of the landscape (including factors such as soil pH, heavy metal content and topography) and legislative restrictions.
- The model was based on data from the 2004 Agricultural Survey but has since been updated to include data on cropping and livestock from the 2015 Agricultural Surveys of England and Wales (Defra, 2015; Welsh Government, 2015). For this project livestock nitrogen loading calculations were adjusted to reflect the broad changes in livestock numbers that have occurred since 2015 (i.e., sheep -0.4%, cattle +0.9%, pigs +7% and poultry +32%). In addition, some modifications to the model were made for this project to reflect the physical characteristics required for this assessment (exclusions of slopes >12° rather than >16°), current legislative requirements and additional exclusion areas (e.g., the areas around Scheduled monuments).
- The GIS-based software uses a rule-based algorithm to decide how and where organic materials should be allocated to the available landbank. The rules are derived from restrictions and constraints such as land designations (e.g., SSSIs or SPZs), legislative and code of practice limits on maximum N application rates and physical characteristics (e.g., slope, proximity to water courses or soil restrictions).

- ALOWANCE contains a 10 x 10 km spatial representation of agricultural survey data (i.e., crop areas in Wales from the 2015 Agricultural Survey), which was used to identify the potential landbank for organic materials. A series of GIS layers were then used to calculate the land that was not available for organic materials based on the identified restrictions and constraints on land application. The model outputs have estimated 1) the potential agricultural landbank capacity, 2) the proportion of the landbank already taken up by farm manures, 3) the landbank after physical, legislative and other restrictions and 4) the landbank remaining for additional organic materials.

Available landbank

- Table A summarises the ALOWANCE estimated landbank in Wales available for recycling new organic materials after accounting for livestock manure N production, physical, legislative and land use restrictions and current sources of organic materials.
- In 2021 there was *c*.1.8 million hectares (ha) of agricultural land in Wales which was reduced to *c*.1.4 million ha (the potential landbank) after excluding, woodland, 'other land' on farms and rough grazing (land areas from the Survey of agriculture and horticulture, June 2021, Welsh Government, 2021).
- Exclusions due to physical and land use restrictions, soil pH and metal concentrations (for non-farm organic materials) and after accounting for current livestock manure production and non-farm organic materials (biosolids, compost, digestate and permitted waste) reduced the landbank by 820,000 hectares. Of the 820,000 ha landbank that was removed, 550,000 ha (approximately 65%) was to accommodate livestock manure N production (both excreted whilst grazing and handled/spread manure); a further *c*.2% was to accommodate current sources of organic materials. Restrictions due to physical, legislative and land use restrictions removed another *c.*252,000 ha.
- After accounting for current applications of manure and organic materials, physical, legislative and land use constraints the potential agricultural landbank available for 'additional organic material' applications was estimated at 579,000 ha (i.e., 41% of the potential landbank of *c.*1.4 million ha).
- In 2021 non-farm derived organic materials were applied to around 18,000 ha of agricultural land (i.e., 3% of the estimated landbank for additional organic materials of 579,000 ha) which suggests that there is capacity for additional organic material applications to land in Wales. However, in some areas along the north Wales coast, Pembrokeshire, south Wales and parts of Gwynedd the available landbank was limited to less than 5% of the agricultural area. In comparison, in mid Wales, Powys and east Carmarthenshire more than 25% of the agricultural area was potentially available for additional organic manure use.
- Organic material applications have not been routinely limited according to soil P in this project; the estimated landbank for additional organic materials (579,000 ha) has been based on current legislation on application rates (which focus on limiting nitrogen applications). However, future legislative changes could include controls on phosphorus applications, for example, matching P offtakes to inputs or excluding applications based on soil P concentrations. To provide an indication of the effect of potential P limited applications ALOWANCE was used to model a scenario where organic material applications were restricted to soils below P Index 3 (i.e., <26 mg/l Olsen extractable P). When this additional restriction was applied the landbank was reduced by a further 126,400 ha giving an estimated landbank available for additional organic materials of 452,600 ha (i.e., 33% of the potential landbank of *c*.1.4 million ha). Under this scenario, the

landbank in Pembrokeshire and South Wales was further reduced and in some areas around Conwy, Denbighshire, Flintshire and Wrexham it was reduced to less than 5% of the total landbank in a 10 x 10 km grid square.

Table A. ALOWANCE estimated landbank in Wales (thousand hectares)

Estimated landbank in Wales	**Area (thousand hectares)**	**Notes**
Theoretical landbank	1800	Agricultural area
Potential landbank for organic materials	1400	After removing woodland, other land on farms and rough grazing
Landbank area removed to account for:		
1. Livestock manure N production	550	Excreted whilst grazing and handled/spread manure
2. Physical, legislative and land use restrictions	252	Including restrictions relating to slopes, proximity to watercourses, soil pH and metal concentrations (not applicable to livestock manures), restrictions in SSSIs etc. and legislative limits.
3. Current sources of organic materials	18	Biosolids, compost, digestate and waste applied under EPR.
Total area removed	820	
Estimated landbank for additional organic materials	579	Remaining landbank after removing land where organic materials cannot be applied and after accounting for current requirements for landbank (1-3, above).
Landbank area removed by P restrictions		
Soil phosphorus (≥ P index 3)	126	Applications only allowed at P Indices 0, 1 and 2
Estimated landbank for additional organic materials (with additional P restriction)	453	

1 Objectives

- The overall objective of this project was to use currently available evidence to investigate the distribution and size of the landbank in Wales available for using organic materials for beneficial use both at national and local scales. The work was delivered in two work packages (WP). WP 1 identified the legislative, physical, land, soil, management, seasonal and climatic barriers to the application of organic materials to land in Wales. WP 2 (this report) will quantify the available landbank for organic materials in Wales, using the ALOWANCE (Agricultural Land – A National Capacity Estimator) tool (Nicholson *et al*., 2012).
- WP 1 collated organic material datasets from Natural Resources Wales (NRW), Welsh Government and other external sources (e.g., Dŵr Cymru Welsh Water or Renewable Energy Assurance Limited (REAL)). In addition, relevant information on the legislative (e.g., Water Resource (Control of Agricultural Pollution) (Wales) Regulations 2021 (WSI, 2021)), physical (e.g., no spreading to slopes >12°)[1], best practice (e.g., Code of Good Agricultural Practice-COGAP (Welsh Assembly Government, 2011)) and other controls (e.g., designated areas such as Sites of Special Scientific Interest (SSSIs)) on organic materials to lands were detailed.
- The data collated in WP 1 has been used to update the appropriate datasets in the ALOWANCE tool, which were used in WP 2 to identify the extent and distribution of the landbank suitable for organic materials in Wales.

2 Introduction

- An estimated 10 million tonnes of organic materials are applied to agricultural land in Wales each year[2]. Organic materials provide major plant nutrients (nitrogen-N, phosphorus-P, potassium-K, sulphur-S, magnesium-Mg) and trace elements (e.g., copper-Cu, zinc-Zn, manganese-Mn, boron-B). The materials also supply organic matter which can improve soil structure, workability, resilience to drought and waterlogging and increase carbon storage. Accounting for manure nutrients in nutrient management plans will reduce fertiliser costs and limit nitrate and phosphorus losses to water, and ammonia and nitrous oxide emissions to air. It is important that applications of organic materials are managed carefully to minimise direct contamination of watercourses and the wider environment.
- In 2021, more than 90% of the land area of Wales was classified as agricultural land (1.8 million ha on farm holdings and 180,000 ha of common rough grazing) (Welsh Government, 2021). Welsh agriculture is dominated by grassland (permanent pasture and sole-rights rough grazing) which accounts for 78% (1.4 million ha) of the total area on farms with significant variation in use (e.g., improved, natural or semi-natural) and management (e.g., stocking rate or cutting regime). In comparison, tillage accounts for 14% (0.25 million ha) of the area, 7% is woodland (0.12 million ha) and the remaining 1% 'other' land on farms (Welsh Government, 2021). Of the 250,000 ha of

[1] The Water Resource (Control of Agricultural Pollution) (Wales) Regulations only limits spreading to slopes >12° if there is 'significant risk of pollution'. The ALOWANCE model is not able to assess if there is 'significant risk of pollution' (as per the COAPR) so all land where the slope is >12° is removed from the available landbank. Potentially this could remove some land where spreading could be permitted under COAPR. However, it should be noted that, for example, Defra guidance rates the risk of runoff from slopes >7° as 'high'.

[2] Based on livestock numbers from the June 2021 Agricultural Survey and standard manure output values (Welsh Government, 2021); data on compost and digestate production from Renewable Energy Assurance Limited; data on biosolids production from Dŵr Cymru and data on permitted waste from Natural Resources Wales.

tilled land in 2021, 62% (*c*.156,000 ha) was grass under 5 years old and 38% (94,000 ha) was in arable and horticulture production (more than 50% of which was cereal crops).

- The optimal zones for agricultural production are related to both climatic and soil conditions; interaction between these factors influences the productivity of agricultural land. Of the total land area of Wales, 60% is more than 150 m above sea level, and 27% is more than 300 m above sea level (Russell *et al*., 2011), where the climate will limit the potential for agricultural crop production. In addition, acid soils and impeded drainage have limited arable cropping and grassland intensification over large parts of Wales. As a result, around 75% of land is classified as Agricultural Land Classification (ALC) classes 3b, 4 and 5 (i.e., mainly unsuitable for arable cropping, Figure 1). Similarly, around 80% of the agricultural land in Wales has been designated under the Less Favoured Area (LFA) Directive (EU Directive 75/268/EEC of 28 April 1975) (Welsh Government, 2018, Figure 2). LFA land is characterised by challenging climatic limitations and shallow, stony and/or peaty soils with limited agricultural and forestry potential and below average economic returns (Armstrong, 2016). Consequently, large areas of agricultural land in Wales are not suitable or available for applications of organic materials, although may be subject to grazing deposition.

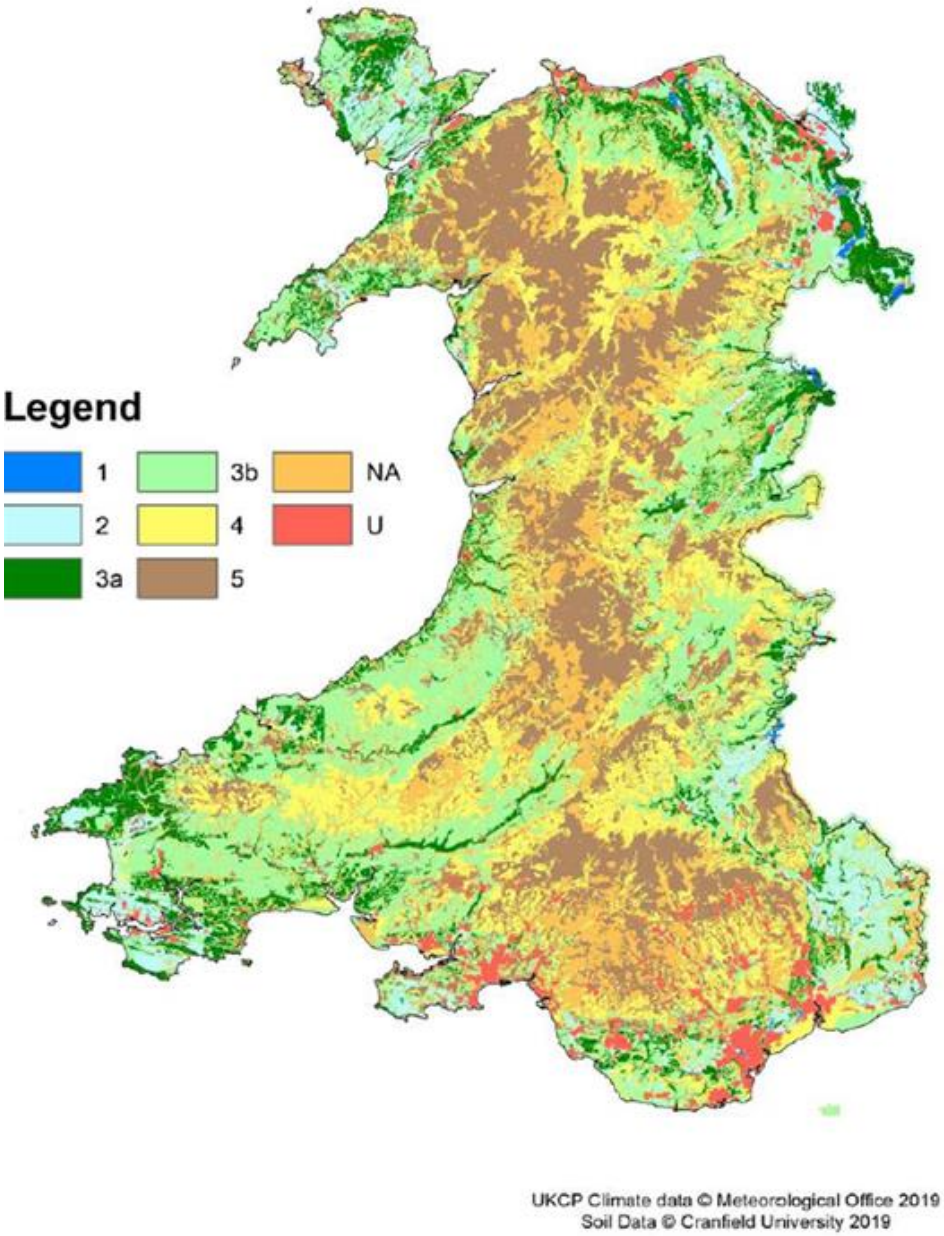


Figure 1. Predictive agricultural land classification (ALC) map for Wales (Source: Keay and Hannam, 2020). Map shows ALC grades and subgrades for agricultural land and categories used for non-agricultural land. Grade 1: excellent quality agricultural land (wide range of arable and horticultural crops with high yields), Grade 2: very good quality agricultural land (wide range of arable and horticultural crops but yields lower than grade 1), Grade 3a: good quality agricultural land (arable crops with moderate to high yield and grass), Grade 3b: moderate quality agricultural land (arable crops with moderate yield and grass), Grade 4: poor quality agricultural land (mainly grass with moderate to high yield), Grade 5: very poor quality agricultural land (permanent pasture or rough grazing), NA: non-agricultural land (golf courses, private parks, allotments etc.) and U: urban land.

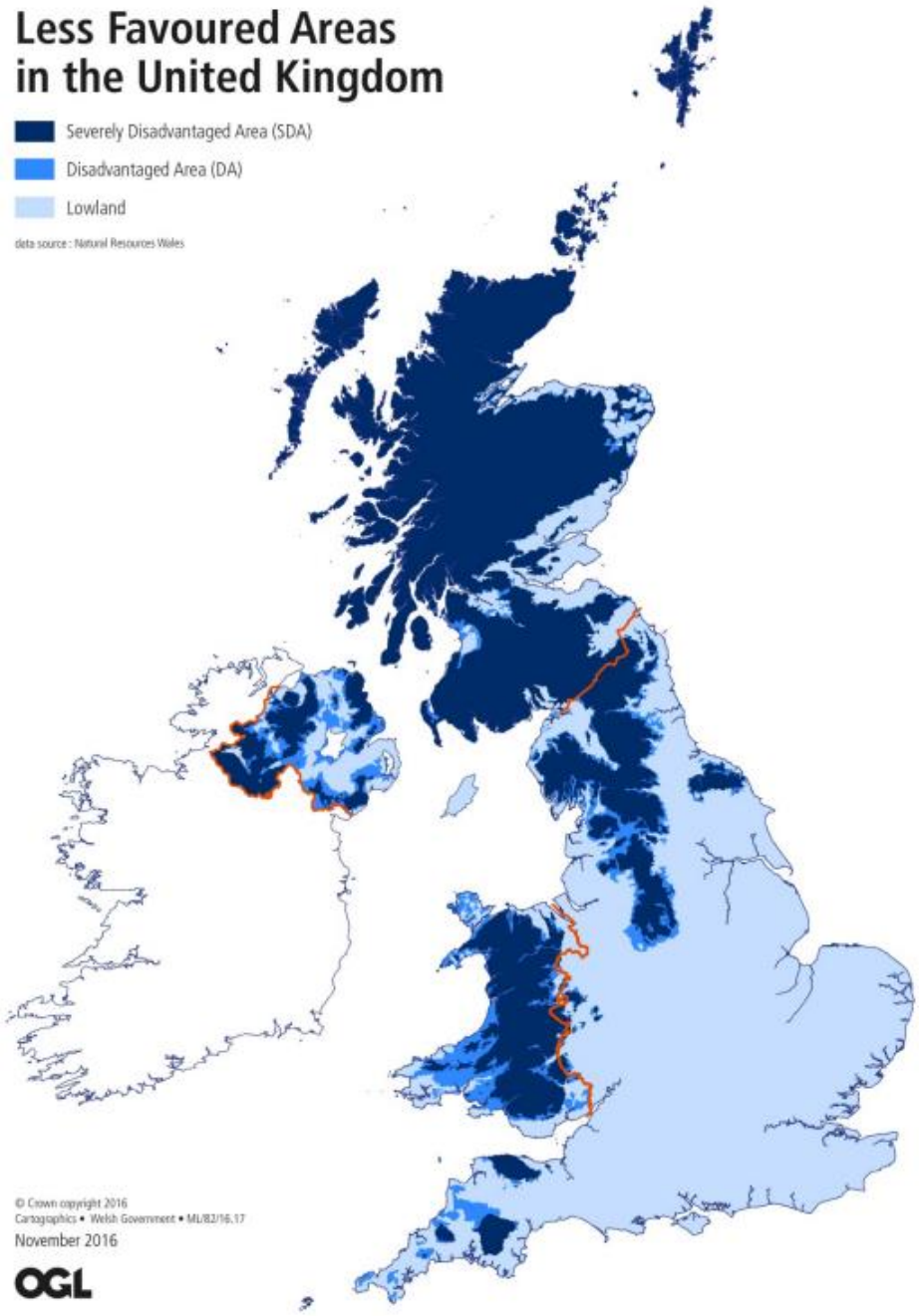


Figure 2. Less favoured areas in the United Kingdom. Source (Welsh Government, 2022)

3 ALOWANCE software

- The ALOWANCE (**A**gricultural **L**and and **O**rganic **W**aste: **A N**ational **C**apacity **E**stimator) software was designed to calculate the agricultural landbank available to accommodate the application of organic materials from farm and non-farm sources, based on nitrogen (N) production and loading rates, the physical characteristics of the landscape and legislative restrictions (Nicholson *et al*., 2012).
- ALOWANCE consists of GIS-based software and has an embedded methodology for calculating: 1) the potential agricultural landbank capacity; 2) current farm manure nitrogen-N production; 3) the proportion of the landbank already taken up by farm manure N loadings and 4) the landbank remaining for non-farm derived organic materials. ALOWANCE can be used to identify areas in Wales where there is a potential shortage or surplus of available agricultural land for using organic materials.
- The ALOWANCE model is described in more detail by Nicholson *et al.,* 2012 and in the project report to Defra which details the model development (ADAS *et al.,* 2007). The model was based on data from the 2004 Agricultural Survey but has since been updated to include data on cropping and livestock from the 2015 Agricultural Surveys of England and Wales (Defra, 2015; Welsh Government, 2015)[3]. For this project livestock nitrogen loading calculations were adjusted to reflect the broad changes in livestock numbers that have occurred since 2015 (i.e., sheep -0.4%, cattle +0.9%, pigs +7% and poultry +32%). In addition, some modifications to the model were made for this project to reflect the physical characteristics required for this assessment (exclusions of slopes >12° rather than >16°), current legislative requirements and additional exclusion areas (e.g., the areas around Scheduled monuments).

3.1 Theoretical landbank (agricultural area)

- ALOWANCE contains a 10 x 10 km spatial representation of Agricultural Survey data (i.e., crop areas in Wales from June 2015) to enable the agricultural land area potentially available for the application of organic materials to be quantified and located. The agricultural survey data contains information on the crops grown on each farm split into arable crops, vegetables and salad, fruit, nurseries and flowers, glasshouse and protected crops, and grass. Rough grazing is not included in ALOWANCE as it is not suitable for spreading of organic materials. The survey information is available in a 1 km grid square format, which has been converted using algorithms from the annual survey of agricultural and horticultural activities. Note that the survey is a sample survey and data are only sought from a proportion of farms each year; data from non-surveyed farms are interpolated from the most recent data for those farms using the trends on comparable farms. Data are collected at the level of the individual farm, and whilst the total area of crops (or animals on a farm) is known the precise location where crops are grown (or animals graze) is not. Geographic estimates are made based on the farm address or known digital field boundaries. For confidentially reasons, prior to use in ALOWANCE this dataset was converted into a 10 x 10 km spatial representation of land use.
- So that different constraints on the spreading of organic materials can be applied ALOWANCE splits the agricultural area into arable land, grassland (grass sown in the last five years and permanent grassland), legumes and ready-to-eat (RTE) crops. RTE crops include lettuce, radish, onions, beans, vining/podded peas, mangetout, cabbage, cauliflower, calabrese/broccoli, courgettes, celery, red beet, carrots, herbs, asparagus, garlic, shallots, spinach, chicory, celeriac,

[3] Although the model includes data for both England and Wales the current project only used data for Wales.

nuts, top fruit, soft fruit, stone fruit and vines. Specifically, ALOWANCE removes the area of peas and beans from the available landbank (no N requirement) and assumes that RTE crop areas have no capacity to receive manures or non-farm organic materials. In practice, PAS 100 compost, pasteurised PAS 110 digestate (WRAP, 2016) and batch stored, or composted manure (FSA, 2009) can be applied to some RTE crops before drilling or planting. This land is excluded from the available landbank by ALOWANCE. However, given that RTE crops account for <0.5% of the agricultural area in Wales (and only a proportion of that area will receive pre-drilling or planting applications) excluding this crop area will not have a significant effect on the total landbank available.

- Figure 3 shows the agricultural area of Wales in a series of 10 x 10 km grid squares coloured according to land availability. Each square potentially contains 10,000 ha of agricultural land; red squares show areas that have the least available land (<500 ha), and bright green indicates those areas that have the most available land (>2501 ha). Note that the only restrictions applied to this map are non-agricultural (urban) areas. Figure 4 shows the agricultural area of Wales which is a) arable or b) grassland (grass sown in the last five years and permanent pasture) according to the 2015 Agricultural Survey. The majority of the 10 x 10 km grid squares in the arable map (Figure 4a) are red, indicating the small amount (less than 7% of total) of arable land in Wales.

3.2 Landbank for organic materials

- The potential landbank (prior to any organic material additions) was calculated by considering the proportion of each 10 x 10 km grid cell that was agricultural land, and within this how much was excluded by physical or legislative restrictions. Data on the N content of materials applied to land (and hence the landbank required) was based on 'typical' values for each material type from the Nutrient Management Guide (RB209) (AHDB, 2021), which are derived from a database of organic material analyses from UK sources. RB209 is recognised as the industry standard guidance for nutrient management planning in England and Wales. It is designed to help farmers make the most of organic materials whilst balancing the benefits of fertiliser use against the costs (both economic and environmental). In practice, livestock manures and other organic materials will have a wide range of N contents based on factors such as livestock type, livestock diet or feedstock type (for compost, digestate etc.). It is not practicable to use measured values for organic material N contents as there is currently no central resource for collating nutrient contents of organic materials and not all materials will be analysed prior to spreading to land.
- ALOWANCE was used to identify the landbank available for organic material applications. Where less than 5% of the land in a 10 km x 10k m square is suitable then it can be considered that there is very limited capacity for additional organic material use in that square. Where more than 25% of the land is suitable it can be assumed that there is significant capacity for additional organic material use in that square.
- If ALOWANCE calculates an excess of N in a particular grid square (e.g., from a large poultry unit) the excess N is distributed across neighbouring grid squares up to a maximum specified distance for each material (i.e., poultry manure 20 km, other manures 10 km, biosolids 30 km, green compost 20 km, digestate 30 km).
- Also, note that ALOWANCE will estimate the maximum available landbank as it does not consider other social and economic factors that may influence land availability for organic materials, such as farmer, retailer, and public acceptance. In addition, seasonal factors affecting the availability of the landbank are not accounted for (e.g., closed periods, flooding, weather conditions etc.). Also, ALOWANCE predictions are based on average conditions for a 10 km by 10 km grid square

and do not necessarily reflect the physical restrictions for an individual field within that grid square.

Figure 3. Agricultural land (theoretical landbank) in Wales (hectares). Map shows land availability before restrictions according to physical characteristics or legislative restrictions.

One grid square = 10,000 ha.

a. Arable

b. Grassland

Figure 4. Agricultural land (theoretical landbank) (ha) in Wales. Maps show land availability before restrictions according to physical characteristics or legislative restrictions, a) arable and b) grassland. One grid square = 10,000 ha

3.3 Organic materials

- Maintaining an appropriate level of soil fertility by the careful use of organic materials (fertiliser derived from animal, plant or human sources including livestock manure), lime and if needed manufactured fertilisers (produced by an industrial process), will help to maximise the crop yield and profitability of agricultural production. However, it is important that the application of organic materials only takes place when land, soil and weather conditions are appropriate and when the nutrients supplied are needed by the crop to reduce the risks of soil, water or air pollution. Ensuring that any nutrients applied are taken up by crops is an indirect way of ensuring environmental protection. Legislation has been introduced to control nitrogen application rates, timings, location, and storage of organic materials to reduce their environmental impact.
- To realise the benefits of organic materials there must be land that is both suitable and accessible for applications by machinery. Not all the 1.8 million ha of agricultural land in Wales is suitable for applying organic materials due to climatic, physical and practical constraints (e.g., steep slopes or proximity to water), and legislative restrictions. For example, upland rough grazing will generally be unsuitable for organic material applications due to steep slopes and low nutrient requirements. In comparison, arable production usually takes place on land with fewer climatic and physical constraints and crops have a recognised requirement for nutrients.

4 Livestock manures

- Livestock manure makes up the majority (almost 90%) of organic materials spread to land in Wales. In June 2021 (based on data from the June 2021 Agricultural Survey), there were *c*.21 million agricultural livestock in Wales comprising of 1.1 million cattle (dairy and beef), 9.5 million sheep, 27,000 pigs and 10.3 million poultry (Welsh Government, 2021). Most of the handled manures (i.e., excreta from housed stock) are from cattle. The ALOWANCE software combines livestock numbers (Table 1) from the June 2021 Agricultural Survey with farm manure N production data (kg N/animal/year) for each livestock type to calculate livestock N loadings (after adjustments for occupancy) to agricultural land, Figure 5, below.
- ALOWANCE assumed nitrogen production for each livestock type is detailed in Table 2 and is equivalent to the quantity of N produced after losses (as ammonia, nitrous oxide, nitric oxide and di-nitrogen or as N in leachate) during housing and storage are accounted for. The figures in Table 2 have been corrected for occupancy and can be used as direct multipliers with animal numbers from the Agricultural Census. The correction accounts for the fact that some livestock, e.g., broilers, may have an occupancy on the farm of less than 365 days.
- The model assumes that manure is applied to suitable land closest to where it is produced; as noted previously, where there is an excess of N in any grid square this will be distributed across neighbouring grid squares. In this project it was assumed that all livestock manures (and other organic materials) produced in Wales were applied in Wales; there is no publicly available data on how much organic material is exported between countries. The amount of material that is applied outside of Wales is expected to be small because transport costs are likely to be high (especially for slurry or digestate where the dry matter content is low).

Table 1. Livestock numbers in Wales (June 2021) (Welsh Government, 2021).

	Livestock type	Number[1]
Dairy	<1 year	83,100
	1-2 years	74,100
	≥2 years no calf	35,900
	≥2 years with calf	255,400
Beef	<1 year	118,300
	1-2 years	93,300
	≥2 years no calf	39,400
	≥2 years with calf	159,500
Male cattle	<1 year	142,100
	1-2 years	94,800
	≥2 years	32,700
Total cattle		1,128,600
Sheep	Ewes for breeding	4,373,100
	Ewes for cull	253,500
	Rams for service	100,300
	Other sheep (≥1 year)	89,800
	Lambs (<1 year)	4,647,700
Total sheep		9,464,300
Pigs	Breeding	3,000
	Fattening	24,200
Total pigs		27,200
Poultry	Chickens (layers)	3,148,500
	Chickens (broilers)	6,537,800
	Chickens (breeding)	471,400
	Turkey	100,100
	Other birds	94,500
Total poultry		10,352,300

Table 2. ALOWANCE assumed N production (kg/head/year), proportion of manure which is handled (excreta produced whilst housed) and proportion of handled manure which is solid.

Survey category	**Category code**	**N production (kg/head/year)[1]**	**Handled manure (%)[2]**	**Solid manure** (%)	**Occupancy** (%)
Cattle					
All dairy cows & heifers that have calved	K1	101	62	34	100
Heifers in 1st calf >2 years/1-2 years	K2, K3	61	35	34	100
Other females for dairy herd replacement >2 years/1-2 years	K4, K5	61	35	82	100
All beef cows & heifers that have calved	K6	83	38	82	100
Beef heifers in 1st calf >2 years/1-2 years	K7, K8	61	38	82	100
Other females for beef herd replacement >2 years/1-2 years	K9, K10	50	38	82	100
Bulls for service >2 years	K11	48	35	82	100
Bulls for service 1-2 years	K12	50	35	82	100
Females intended for slaughter >2 years/1-2 years	K13, K14	50	38	82	100
Other male cattle >2 years/1-2 years	K15, K16	50	38	82	100
Intended for slaughter as calves	K17	8.8	38	100	100
Other female calves/other male calves	K18, K19	29	45	82	100
Pigs					
Sows in pig/suckled or dry sows for further breeding	L1, L3	17	100	25	100
Gilts in pig	L2	13.9	100	25	100
Boars used for service	L4	17.5	100	100	100
Gilts 50 kg & over for breeding	L5	13.9	100	65	80

Survey category	**Category code**	**N production (kg/head/year)[1]**	**Handled manure (%)[2]**	**Solid manure** (%)	**Occupancy** (%)
Barren sows for fattening	L7	12.3	100	65	88
Growers >110 kg	L10	12.3	100	65	86
Growers 80-110 kg	L11	12.3	100	65	86
Growers 50-80 kg	L12	8.8	100	65	88
Growers 20-50 kg	L13	8.8	100	65	88
Weaners <20 kg	L14	1.5	100	50	82
Poultry					
Birds in laying flock (caged)	N31, N32	0.41	100	100	97
Layers (free range)	N33	0.55	80	100	97
Broilers	N10	0.39	100	0	85
Layer/broiler breeders/cocks	N5, N6, N7	0.74	100	100	95
Growing pullets up to point of lay	N2	0.24	100	100	89
Turkeys	N15	1.19	100	0	88
Ducks	N13	0.9	100	100	83
Geese	N14	1.19	100	100	88
All other birds	N16	0.9	100	100	
Sheep					
All sheep	M1, M4, M7, M9, M13, M14	9.8	5	100	100
Lambs under 1 year	M17	0.6	0	100	100

[1]N production is the quantity of N produced after losses during housing and storage are accounted for. The figures have been corrected for occupancy and can be used as direct multipliers with animal numbers from the Agricultural Survey. [2]Data from Webb and Misselbrook, 2004.

- ALOWANCE subdivides N loading into field deposited N (i.e., deposited directly in the field by grazing livestock) and manure N handled as FYM (straw-based farmyard manure), slurry, poultry litter or poultry manure. For example, dairy cattle may excrete, a) during grazing; b) during winter housing; c) during 'summer' housing i.e., in milking parlours; d) on collecting yards in winter; e) on collecting yards in summer and f) on feeding yards (Table 3). Overall, 38% of dairy cattle excreta was estimated to be deposited during grazing over the course of a year (based on data from Webb and Misselbrook, 2004) with the remaining 62% as handled manure (i.e., produced whilst housed, in milking parlours or on collecting yards). Assumptions for other cattle (i.e., dairy cattle not in-milk and beef cattle) and sheep are also included in Table 3. For pigs and poultry (other than free range layers), it is assumed that 100% of manure comes from housed livestock.

Table 3. ALOWANCE apportionment of manure by livestock type and location

Excreta sources	Dairy cattle (In milk)	Dairy cattle (Not in milk)	Beef cattle	Sheep
Grazing	38	65	62	95
Summer				
Housing	7			
Collecting yards	12			
Winter				
Housing	31	31	31	4
Feed yard	3	4	7	
Collecting yard	9			1

- The FYM/slurry split in ALOWANCE is based on published data on the proportion of manure excreted as slurry or FYM as reported in The National Inventory and Map of Livestock Manure Loadings to Agricultural Land: Manures-GIS (ADAS and North Wyke Research, 2008). The proportion of excreta as slurry is around 70% for dairy cattle, 20% for beef cattle, 75% for breeding gilts/sows and 35% for growing/fattening pigs. More details are included in Table 2. This data is consistent with more recent values reported by Smith and Williams, 2016.
- Figure 5 shows the total N production (kg) in each 10 x 10 km grid square (i.e., total N production from poultry manure, poultry litter, FYM, slurry and excreta deposited during grazing). It shows areas where N production is high such as Pembrokeshire and Carmarthenshire. In comparison, Figure 6 shows the typical N loading from livestock manure (sum of N from spread manure and excreta deposited during grazing) per hectare of agricultural land in each 10 x 10 km grid square based on 2021 livestock numbers and N production rates (kg/head/year) for various livestock types in Table 2. In most areas N loadings are between 100-150 kg N/ha. Note that some areas that had high N production (red squares in Figure 5) do not result in excessive N loading (i.e., they are not red in Figure 6). This is because although N production is high in these areas the agricultural land area is large and so the rate per hectare may be less than in areas with lower N production but less agricultural land.

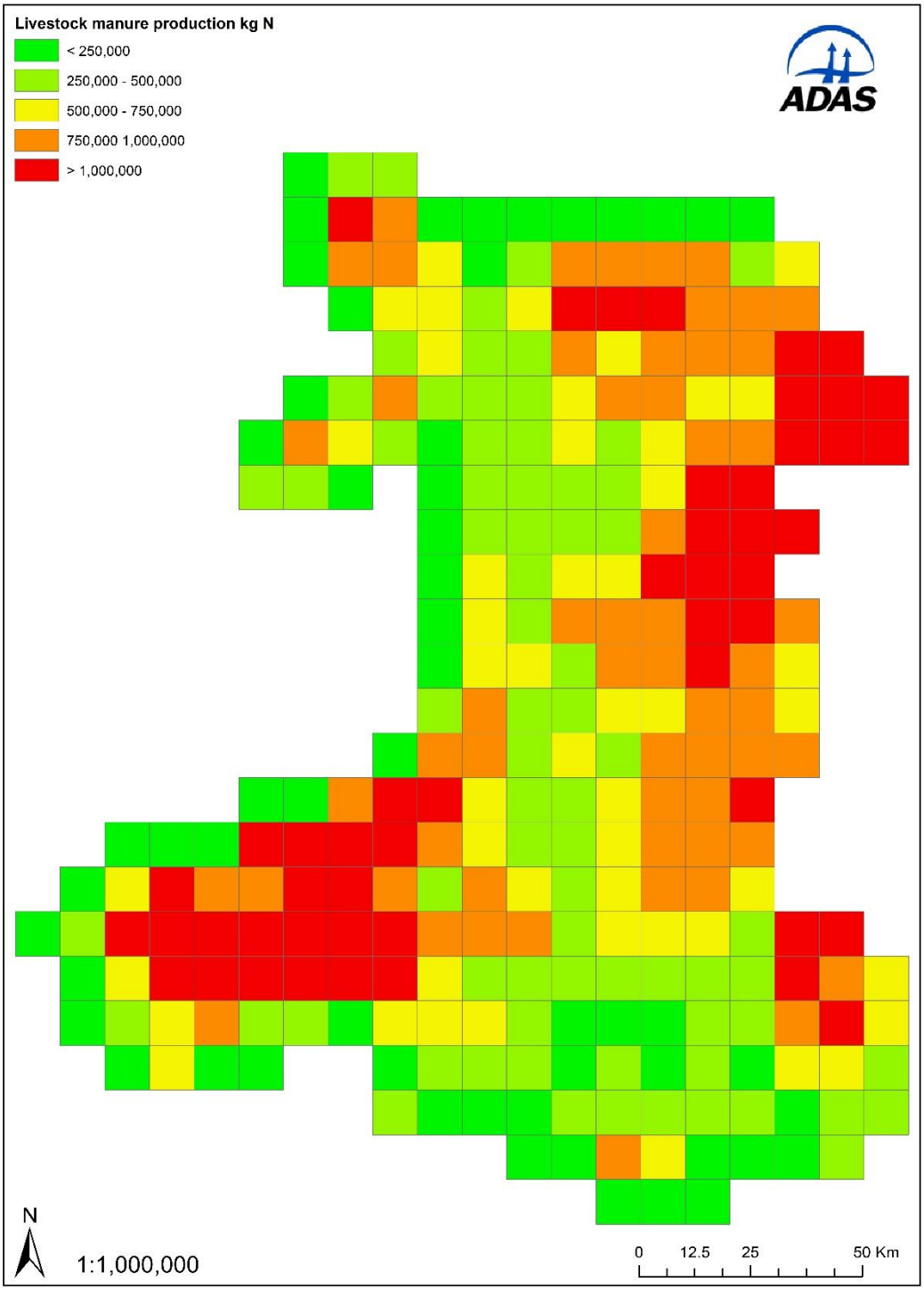


Figure 5. Nitrogen production from livestock manures (kg N). Sum of N from spread manure and excreta deposited during grazing. One grid square = 10,000 ha

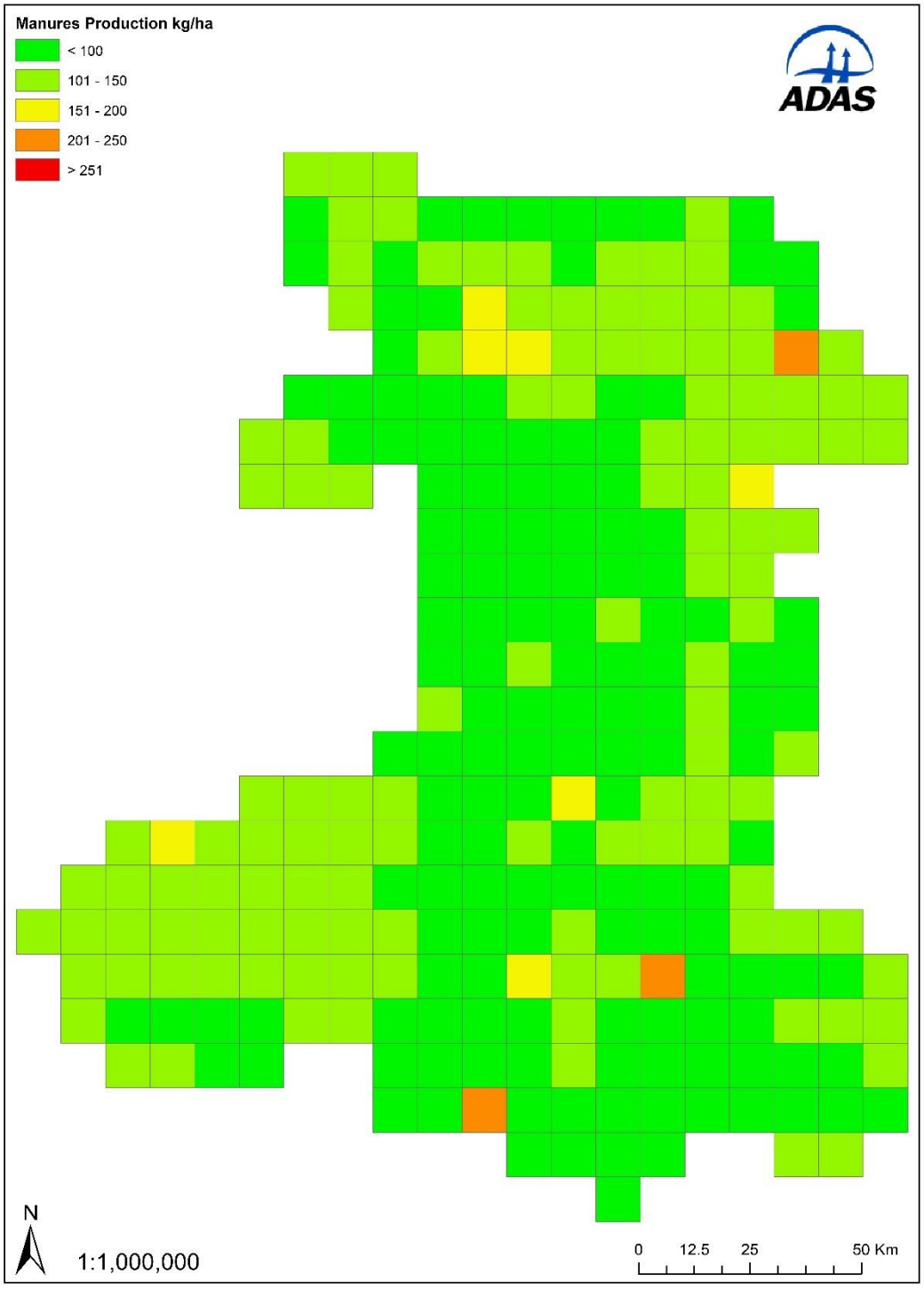


Figure 6. Nitrogen loading from livestock manures (kg N/ha of agricultural land). Sum of N from spread manure and excreta deposited during grazing. One grid square = 10,000 ha.

5 Other organic materials

- For other organic materials, information on the quantity produced for land spreading (e.g., biosolids or compost) was combined with data on the 'typical' N content of the materials as reported in AHDB's Nutrient Management Guide (RB209), to calculate the N loading to agricultural land in each 10 x 10 km grid square. Table 4 below, includes details on the quantity of PAS 100 compost, PAS 110 digestate and biosolids produced in Wales and spread to agricultural land.

Table 4. Tonnes (fresh weight) of compost, food/crop-based digestate and biosolids spread to agricultural land in Wales and approximate hectares of landbank required.

Organic material	Quantity produced (tonnes fresh weight)	N content (kg/tonne fresh weight)[2]	Approximate hectares (at 250 kg N/ha)
Compost (PAS 100)	57,000 [38,000][1]		1,000
Green		7.5	
Green/food		11	
Digestate (PAS 110)	219,000		4,500
Whole		4.8	
Separated liquid		4.5	
Separated fibre		8.9	
		N Content (% dry solids)	
Biosolids	128,000	4.6	6,000
Total			11,500

[1]. Around 65% of compost is applied to agricultural land. [2]. AHDB (2021) Nutrient Management Guide values for green, green/food compost and food-based digestate. [3]. Data supplied by Dŵr Cymru on average N content of biosolids applied to agricultural land.

5.1 Certified digestate

- Data on digestate quantities to land was combined from the following sources:
    - Compost/Biofertiliser Annual Report 2020 (REAL, 2021).
    - The Official Information Portal on Anaerobic Digestion (Biogas map). Includes information on feedstock type/quantity.
    - Biofertiliser Certification Scheme (Certified Producers). Identifies certified digestate producers.
    - Renewable Energy Assurance Limited (REAL) supplied data on digestate production and market destination for certified plants in Wales.
    - Typical nutrient content of food-based digestate from the Nutrient Management Guide (RB209) Section 2. Organic Materials (AHDB, 2021).
- The data sources identified eight certified (PAS 110) digestate plants in Wales; the predominate feedstock (80%) was food waste, 6% was purpose grown crops, 4% slurry and 10% other wastes. Data supplied by REAL indicated that the annual feedstock input to the eight digestate plants was *c.*285,000 tonnes per annum; total digestate to agricultural land was calculated as *c.*219,000

tonnes fresh weight. Also, to avoid double counting digestate produced from slurry feedstocks was not included in the total applied to land. Note that only around 4% of the digestate feedstock was slurry.

5.2 Certified compost

- Data on compost quantities to land was combined from the following sources:
    - Compost/Biofertiliser Annual Report 2020 (REAL, 2021).
    - Biofertiliser Certification Scheme (Certified Producers). Identifies certified compost producers in Wales.
    - Renewable Energy Assurance Limited (REAL) supplied data on compost production and market destination for certified plants in Wales.
    - WRAP Cymru (2016) Survey of green waste compost production capacity in Wales
    - Typical nutrient content of compost from the Nutrient Management Guide (RB209) Section 2. Organic Materials (AHDB, 2021).
- The data sources identified ten certified (PAS 100) compost plants in Wales; those applying to agricultural land used exclusively green waste feedstocks. Total compost output was calculated as *c*.57.000 tonnes fresh weight of which 66% (38,000 tonnes fresh weight) went to agriculture and soil grown horticulture.

5.3 Biosolids

- Data on biosolids to land was combined from the following sources:
    - NRW supplied the Annual Return Natural Resources, Sludge quantity and quality reports for Dŵr Cymru for Wales and England.
    - ADAS data on Sludge Treatment Centres
    - Dŵr Cymru Bioresources Market Information 2020-21 (Bioresources market information).

- The data supplied by DCWW reported that 32,070 tonnes of biosolids (tonnes of dry solids) was applied to agricultural land which equates to *c*.128,000 tonnes on a fresh weight basis (based on a dry matter content of *c*.25%).

5.4 Summary

- Based on the N content in Table 4 the landbank required for each material has been calculated as 1,000 ha for compost, 4,500 ha for digestate and 6,000 ha for biosolids. In total, 11,500 ha of agricultural land are estimated to be required to reuse compost, digestate and biosolids.

5.5 Other non-farm wastes

- Data for non-farm wastes was supplied by NRW for mobile plant deployments issued under Environmental Permitting (England and Wales) Regulations 2016 (No. 1154) (SI, 2016) from 2016 to 2021. The most recent complete year's data (2020) was used in this project (deployments for land remediation were excluded). Each deployment specified the maximum amount of material that could be applied under that deployment and most referred to multiple material types (i.e., they included materials with a range of EWC codes). Because the amount of material of each type applied under each deployment was not known it was assumed that the total deployment tonnage was split equally between the material types. For example, for a deployment with a limit

of 10,005 tonnes and three waste types 3,335 tonnes of each material were assumed to be applied. The deployment post code was used to identify where the material was spread.

- According to the data supplied by NRW around 100 mobile plant deployments were issued in Wales in 2020 to recover *c*.755,000 tonnes of materials to land. However, the amount of material applied to land may have been less than the amount stated on the permit, which represents the maximum amount of material that can be applied under that deployment. More than twenty types of organic materials were applied under a deployment in 2020 (Table 5). Considering the tonnages of materials indicated on the deployment almost half (49%) of the materials applied under a mobile plant deployment were either sludges from water clarification (31% of total tonnage) or sludge from on-site effluent treatment such as that from the dairy products industry (18%).
- Typical nutrient content of waste materials that are commonly recovered to land are included in RB209 (Table 6) and were used to calculate the N content of the materials described in the mobile plant deployments. Based on an application rate of 250 kg N/ha it was calculated that the waste applied under mobile plant deployment in 2020 would require a landbank of *c*.6,000 ha.

Table 5. Waste types recovered to land under a mobile plant deployment in Wales in 2020 and % of total accounted for by each waste type (blue shading indicates the five most common waste types by permitted tonnage).

Waste code	Description of waste type	% of total
02 01 Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing		
02 01 06	animal faeces, urine and manure (including spoiled straw), effluent, collected separately and treated off-site	1.8
02 01 99	wastes not otherwise specified	0.1
02 02 Wastes from the preparation and processing of meat, fish & other foods of animal origin		
02 02 01	sludges from washing and cleaning	5.4
02 02 02:	animal-tissue waste	0.1
02 02 04	sludges from on-site effluent treatment	6.7
02 03 Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation & processing; conserve production; yeast & yeast extract production, molasses preparation & fermentation		
02 03 01	sludges from washing, cleaning, peeling, centrifuging and separation	2.4
02 03 04	materials unsuitable for consumption or processing	0.2
02 03 05	sludges from on-site effluent treatment	4.7
02 05 Wastes from the dairy products industry		
02 05 01	materials unsuitable for consumption or processing	4.5
02 05 02	sludges from on-site effluent treatment	17.5
02 07 Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea & cocoa)		
02 07 01	wastes from washing, cleaning and mechanical reduction of raw materials	2.5
02 07 02	wastes from spirits distillation	2.7
02 07 05	sludges from on-site effluent treatment	4.2
03 03 Wastes from pulp, paper and cardboard production and processing		
03 03 05	de-inking sludges from paper recycling	0.4
03 03 10	fibre rejects, fibre-, filler- and coating-sludges from mechanical separation	0.2
07 07 Wastes from the MFSU of fine chemicals and chemical products not otherwise specified		

07 07 12	sludges from on-site effluent treatment other than those mentioned in 07 07 11	0.2
17 05 soil (including excavated soil from contaminated sites), stones and dredging spoil		
17 05 06	dredging spoil other than those mentioned in 17 05 05	1.4
19 02 wastes from physico/chemical treatments of waste		
19 02 03	premixed wastes composed only of non-hazardous wastes	2.5
19 02 04:	premixed wastes composed of at least one hazardous waste	0.1
19 05 wastes from aerobic treatment of solid wastes		
19 05 99:	wastes not otherwise specified	0.9
19 06 Wastes from anaerobic treatment of waste		
19 06 05:	liquor from anaerobic treatment of animal and vegetable waste	1.2
19 06 06	digestate from anaerobic treatment of animal and vegetable waste	6.2
19 09 wastes from the preparation of water intended for human consumption or water for industrial use		
19 09 02	sludges from water clarification	31.3

Table 6. Typical nitrogen content of waste derived organic materials (Source: AHDB, 2021 and SRUC, 2019)

Waste-derived materials	Total nitrogen (kg N/t)
Water treatment cake	2.4
Paper crumble (chemically/physically treated)	2.0
Paper crumble (biologically treated)	7.5
Dairy	1.0
Soft Drinks	0.3
General	1.6
Brewing	2.0
Distillery pot ale	2.5
Distillery effluent/sludge	1.5
Brewery wash water	0.3

6 Exclusions and constraints

6.1 Topography

- Slope is an important factor determining whether organic materials can be applied safely. The slope of land affects its suitability for agricultural production through the restrictions steeper slopes impose on mechanisation of crop management and on their vulnerability to soil erosion and surface runoff.
- The application of organic materials to steeply sloping land will pose a higher risk of nutrient losses to water via surface runoff than from material applied to flat or gently sloped land. Defra (2021) states that slopes >11° may have a very high runoff risk, >7° may have high runoff risk, between 3° and 7° may have moderate runoff risk and <3°may have lower runoff risk.
- The legislative requirements of the COAPR 2021 state that "fertiliser must not be spread on land if there is significant risk of pollution, considering the slope of the land, particularly if the slope of the land is more than 12° (20%)" (WSI, 2021). The COAPR 2021 also notes that land with a low run-off risk has an average slope of less than 3°. In comparison, good practice guidance in the COGAP for Wales states that livestock manures and dirty water should not be applied on steep slopes where there is a high risk of run-off throughout the year (Welsh Assembly Government,

2011). However, note that 'steep' is not defined in the COGAP guidance. NRW guidance also states that wastes should not be applied "on steep slopes where run-off is a high risk" (NRW, 2017).

- In line with COAPR guidance ALOWANCE landbank assessments assume that handled manure or other organic materials were not applied where slopes >12°; (Figure 7). The ALOWANCE model is not able to assess if there is 'significant risk of pollution' (as per the COAPR) so all land where the slope is >12° was removed from the available landbank. Potentially this could remove some land where spreading could be permitted under COAPR. However, it should be noted that, for example, Defra guidance rates the risk of runoff from slopes >7° as 'high'.

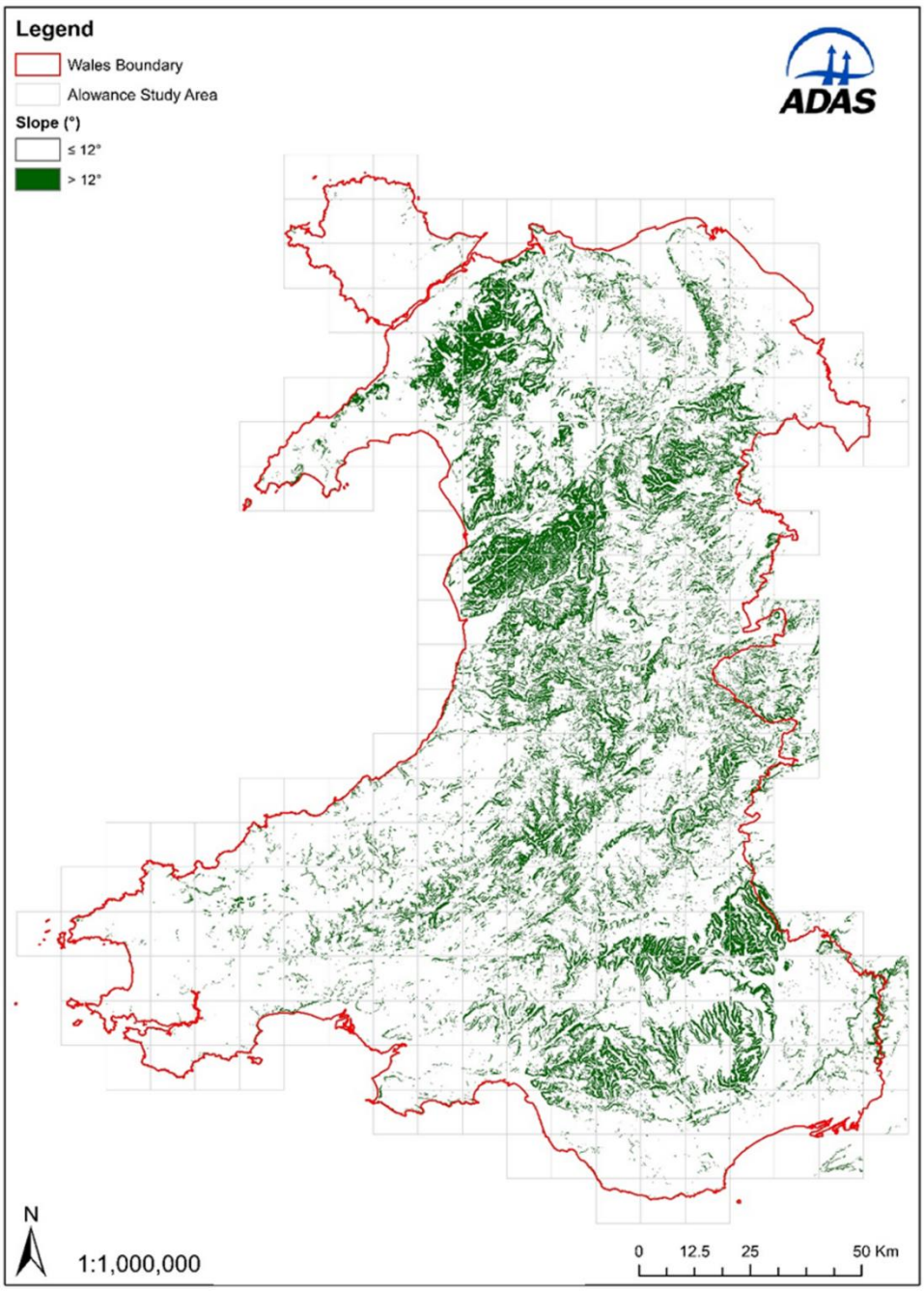


Figure 7. Areas where the slope is >12°

6.2 Surface water, springs, wells and boreholes

- Proximity to watercourses (and conduits for water, e.g., land drains or runoff pathways) controls the potential connectivity between organic manure applications and water. In general, the level of inherent risk of water pollution following organic material applications will be less significant if fields are not close or well connected to a waterbody. However, manure type, soil condition, type and nutrient content, weather conditions, slope, application method and crop will also influence the risk of nutrient loss following land spreading of organic materials.
- The COAPR (2021) states that organic materials should not be spread within 10 m of surface water (includes all rivers, streams, ditches, drains, cuts, culverts, dikes, sluices, sewers, and passages through which water flows, except mains and other pipes) or within 50 m of a spring, well or borehole (Figure 8). Similar guidance is included in COGAP Wales, cross compliance (for those who claim Basic Payment Scheme) and Environmental Permitting Regulations for deployments.
- Datasets from the British Geological Survey (boreholes, wells, and springs) and CEH (rivers and streams) were used to identify where the restrictions should be applied.
- In 2021, 894 million litres of water were supplied each day in Wales by Dŵr Cymru Welsh Water or Hafren Dyfrdwy predominately from surface water sources (93% by volume in 2021) (Drinking Water Inspectorate 2022). Note that the datasets used in this project do not identify private water supplies (in Wales a private supply is one which is not connected to the public mains of Dŵr Cymru Welsh Water or Hafren Dyfrdwy) so it was not possible to exclude areas around these sources from the available landbank. However, private water supplies only account for a small proportion of the water used in Wales. In 2021 around 2% (*c*.68,000 people) of the population in Wales (3.2 million people) used a private water supply which originated from a range of sources including boreholes, natural springs and water courses (Drinking Water Inspectorate, 2022). Unlike public water supplies ground water is a significant source of private water. In 2021 the drinking water inspectorate reported that 49% of private water supplies were from groundwater sources, although a review by Farr *et al*. (2022) suggested that 94% of private supplies came from groundwater sources.
- Based on an exclusion zone of 50 m for each of the reported 14,723 private supplies in Wales an additional 11,562 ha would be excluded from the landbank. This equates to up to 2.5% of the landbank remaining (579,000 ha) after the other exclusions applied in this report have been applied. Note that landbank around private water supplies may already be excluded for other reasons so this represents a worst-case scenario. For completeness, it is recommended that a dataset on private water supplies is included in future estimates of the available landbank for Wales.

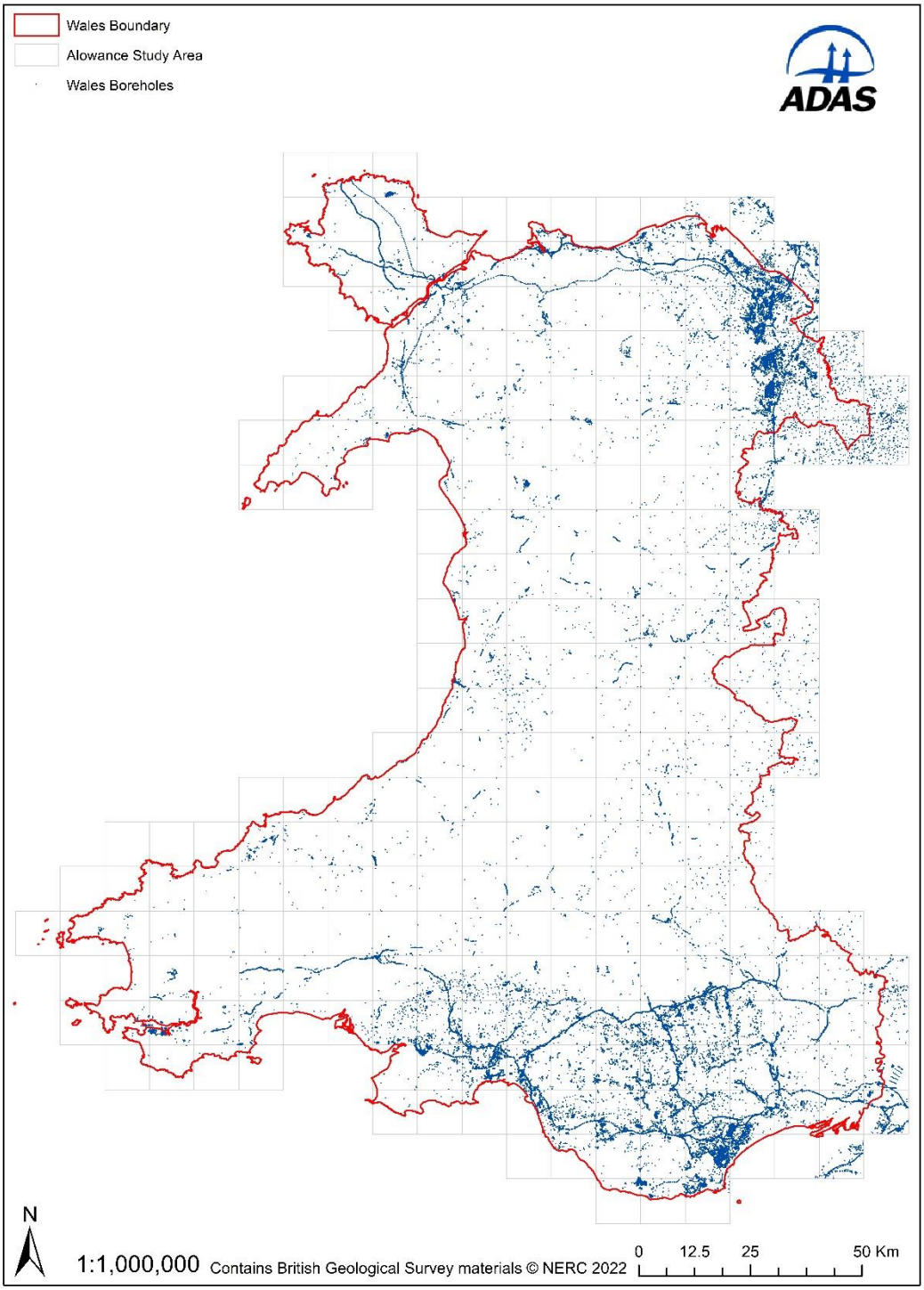


Figure 8. Location of boreholes.

6.3 Source Protection Zones

- Source Protection Zones (SPZs) indicate those areas where groundwater supplies are at risk from potentially polluting activities and accidental releases of pollutants. SPZs are primarily a policy tool used to control activities close to water supplies intended for human consumption. SPZs are not statutory and are mainly for guidance but they do relate to distances and zones defined in legislation where certain activities are restricted (Environment Agency, 2019). Three SPZs (zones 1 to 3) are typically defined for groundwater sources (well, boreholes and springs for potable uses for public drinking water supplies). SPZ1. Inner Protection Zone is defined as the 50-day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres
- NRW do not support the spreading of biosolids or liquid waste within a SPZ1 or within 50 metres of any borehole, well or spring. Applications within a SPZ1 are not permitted under a mobile plant for land spreading permit (SR2010 no4 v6.1) (NRW, 2016).
- Figure 9 shows the locations of SPZ1, SPZ2 and SPZ3 in Wales, however, note that only SPZ1 areas were excluded from the agricultural landbank available for organic material recycling.
- Data on SPZs was obtained from DataMapWales (Source Protection Zones merged).

6.4 Drinking water protected areas and safeguard zones

- The Water Framework Directive specifies that areas requiring special protection under other EC Directives and waters used for the abstraction of drinking water (Article 7) are identified as protected areas. Drinking Water Protected Areas (DrWPAs) are "all bodies of water used for the abstraction of water intended for human consumption providing more than 10 m^3 a day as an average or serving more than 50 persons; and those bodies intended for such use" and for groundwater “all productive water bodies” are designated.
- The objectives for DrWPA are to 1) ensure that, under the water treatment regime applied, the drinking water produced meets the requirements of the Drinking Water Directive and 2) ensure necessary protection in the DrWPA with the aim of avoiding deterioration in water quality in order to reduce the level of purification treatment required in producing drinking water. The first objective is met by achieving the requirements of the Drinking Water Directive and the second by putting in place actions to maintain drinking water quality. According to the Protected Area Register on the NRW website there are 130 DrWPAs for surface water in Wales and 38 for ground water. Of these areas, 62% of surface water DrWPAs were identified as ‘at risk’ and 13% of ground water DrWPAs.
- Where a DrWPA is at risk, a non-statutory safeguard zone is established identifying the catchment area where land use practices are most likely to be causing, or have caused, water quality to deteriorate. Safeguard zones focus pollution prevention and regulatory actions where they are most needed. Groundwater Safeguard Zones are based on Groundwater Source Protection Zones (SPZs), usually the SPZ1 and SPZ 2, and use additional assessment to identify areas, which may or may not coincide with the SPZ, where additional measures are required to ensure that abstraction waters meet Article 7.3 of the WFD.

6.5 Groundwater vulnerability zones

- Groundwater vulnerability maps have been created by NRW and the Environment Agency based on data from the British Geological Survey, the UK Centre for Ecology and Hydrology and the National Soil Resources Institute. The maps provide an assessment of the vulnerability of groundwater to a pollutant discharged at ground level based on the hydrological, geological,

hydrogeological and soil properties within a one-kilometre square grid, Figure 10. The groundwater vulnerability for principal/major (providing significant quantities of water) and secondary/minor (modest amounts of water which supports supplies at a local rather than strategic level) aquifers is expressed from high to low.

  - High: areas that can easily transmit pollution to groundwater. They are characterised by free draining sandy and shallow soils with a high risk of leaching and the absence of low-permeability superficial deposits.
  - Medium: areas that offer some groundwater protection. Intermediate between high and low vulnerability.
  - Low: areas that provide the greatest protection to groundwater from pollution. They are likely to be characterised by slowly permeable soils and/or the presence of low-permeability superficial deposits.

- The maps were designed as a high-level screening tool to indicate whether an activity (e.g., land spreading of organic materials) is in an area of high vulnerability. There is no legal requirement to restrict the landspreading of organic materials in these areas and these areas are shown in Figure 10 for information only.

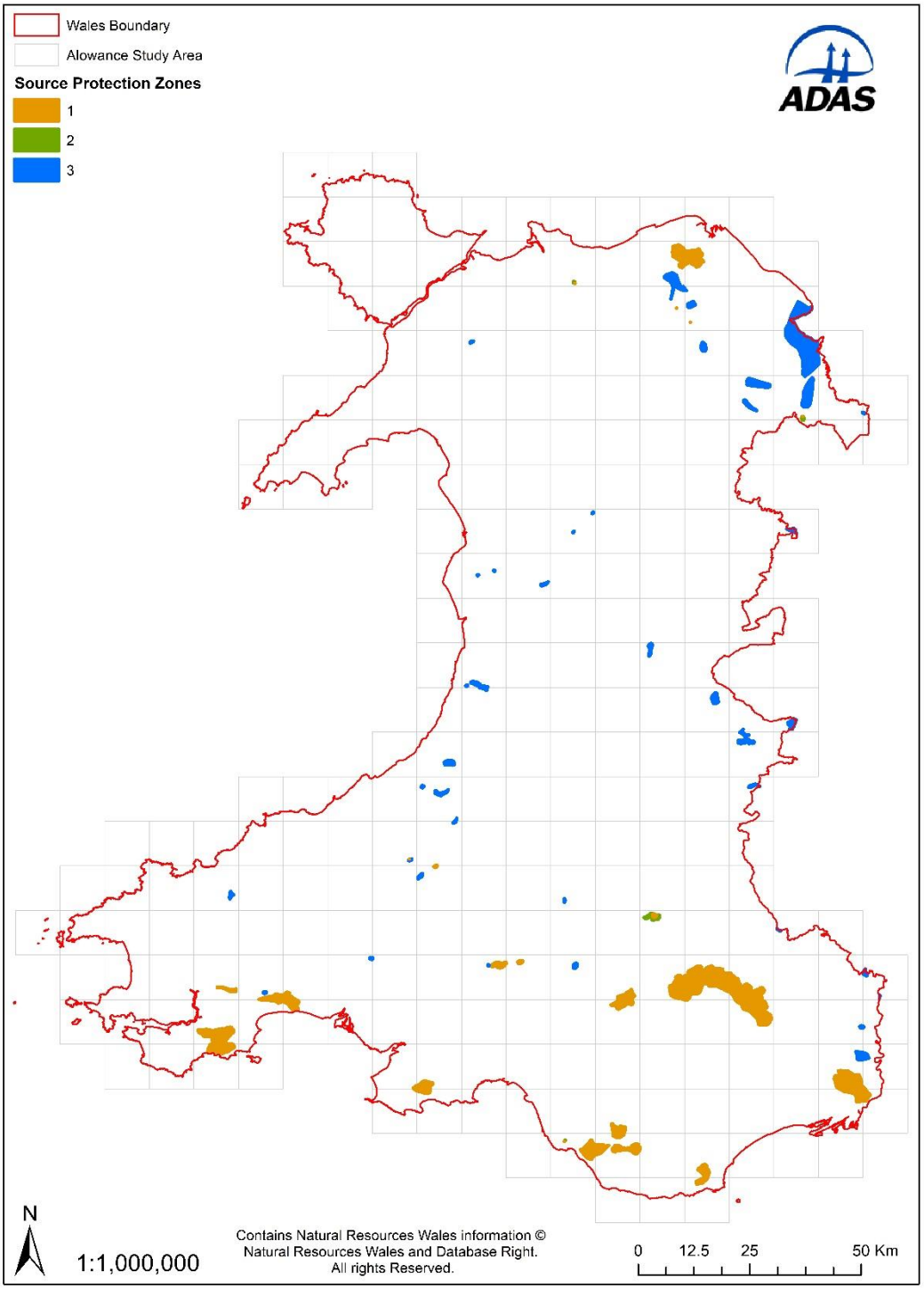


Figure 9. Location of Source Protection Zones 1, 2 and 3.

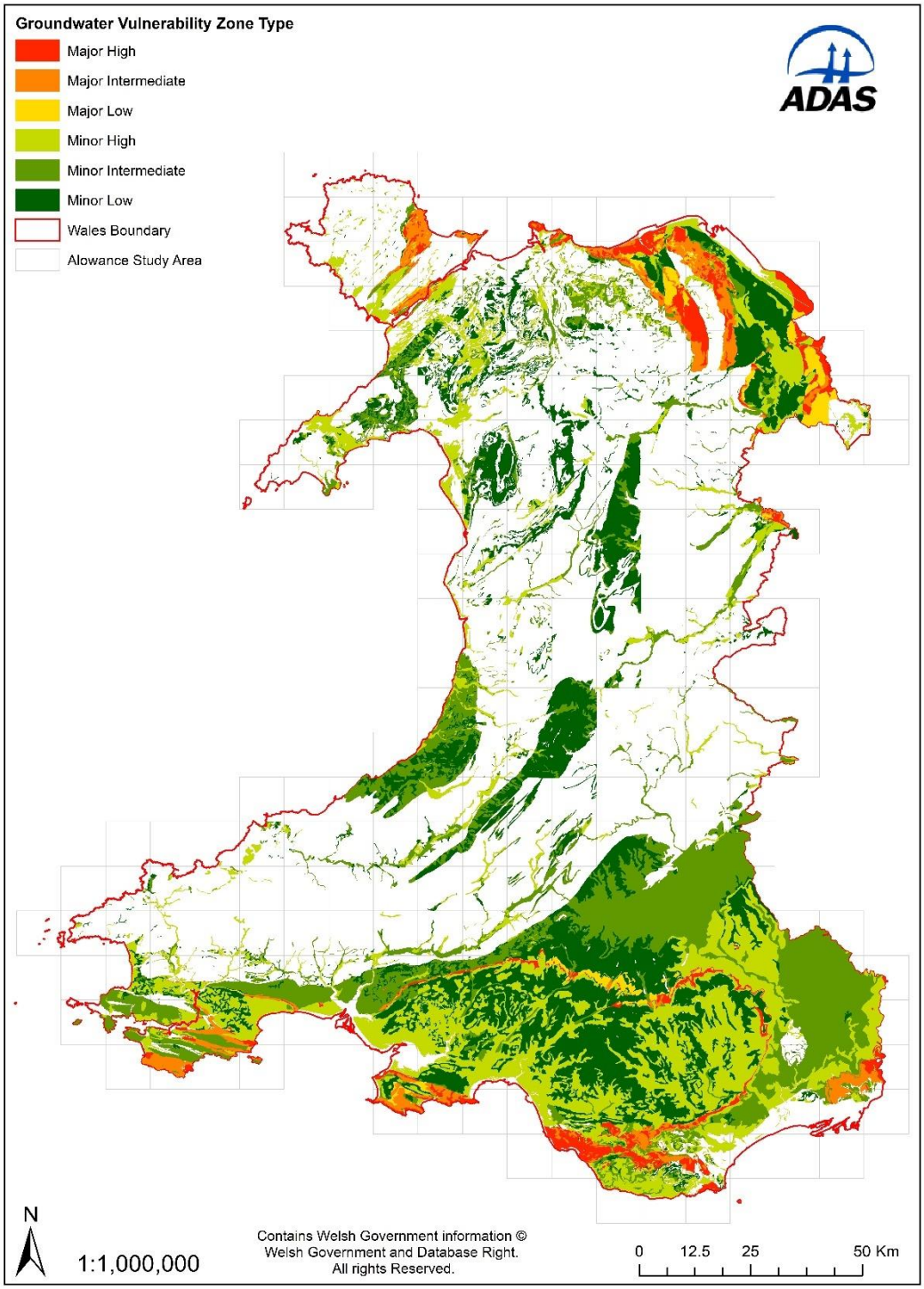


Figure 10. Major and minor aquifers and groundwater vulnerability zones classified as high, intermediate, or low risk of pollution transfer.

6.6 Designated sites

- National statutory designations are divided into two categories: those for protecting landscapes; and those for protecting habitats, species and geology. Landscape designations include Areas of Outstanding Natural Beauty (AONB) and National Parks. Species and habitat designations are: 1. Sites of Special Scientific Interest (SSSIs) which are areas protected under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2002) which contain wildlife or geological or land features that are of special importance[4], 2. National Nature Reserves (NNRs) support nationally important natural and semi-natural terrestrial (or coastal) ecosystems and 3. Local Nature Reserves (LNR) are locally important natural and semi-natural terrestrial (or coastal) ecosystems. Wales has more than 1000 SSSIs[5] (Figure 11) 76 NNR[6] and 62 LNR[7]. Statutory nature conservation designations in Wales include 21 Special Protection Areas (SPAs), more than 90 Special Areas of Conservation (SACs) and 10 Ramsar sites[8].
- Figure 11 shows the location of SSSIs and Figure 12a shows the location of Special Protection Areas (SPA), Special Areas of Conservation (SAC), and Ramsar sites and Figure 12b National Nature Reserves (NNR) and Local Nature Reserves (LNR); SPAs, SACs, Ramsar sites and NNRs are typically also SSSIs.
- Other than legislative/good practice controls, specific controls on organic material applications (and other management practices) on designated sites are bespoke and will relate to the protection of the habitats and species present. Note that the majority of SSSIs will not have any manure applied because of specific conditions listed in the Operations Likely to cause Damage (OLDs) or Potentially Damaging Operations (PDOs) (part of the SSSI management statement) (NRW personal communication). Activities that are included in the OLD/PDO are not prohibited but require prior consent to be issued from NRW. For organic manures permission may be given to apply in a certain way, at a certain rate, or at specific times of the year, or on specific parts of the SSSI.
- The scope of this project does not allow specific conditions to be applied to individual designated sites. Instead, it was assumed that only low readily available nitrogen manure (FYM) could be applied to these sites, under certain circumstances, and that high readily available nitrogen-RAN manures (e.g., slurry and poultry manure) and off-site materials (i.e., compost, digestate, biosolids and permitted wastes) were excluded. The application of permitted waste and biosolids (applied on non-agricultural land or agricultural land growing non-food crops) will be controlled by the deployment process which would ensure that none of these materials would be applied to designated sites.
- In summary, only FYM was allowed to be applied to designated sites, under certain circumstances. The areas were excluded from the agricultural landbank available for the application of all other organic materials.
- Data on the location of designated sites was obtained from DataMapWales.

[4] NRW. Fact sheets for areas of interest
[5] NRW. Types of protected areas of land and sea
[6] NRW. National nature reserves
[7] NRW. Local green spaces
[8] NRW. Sites protected by European and international law

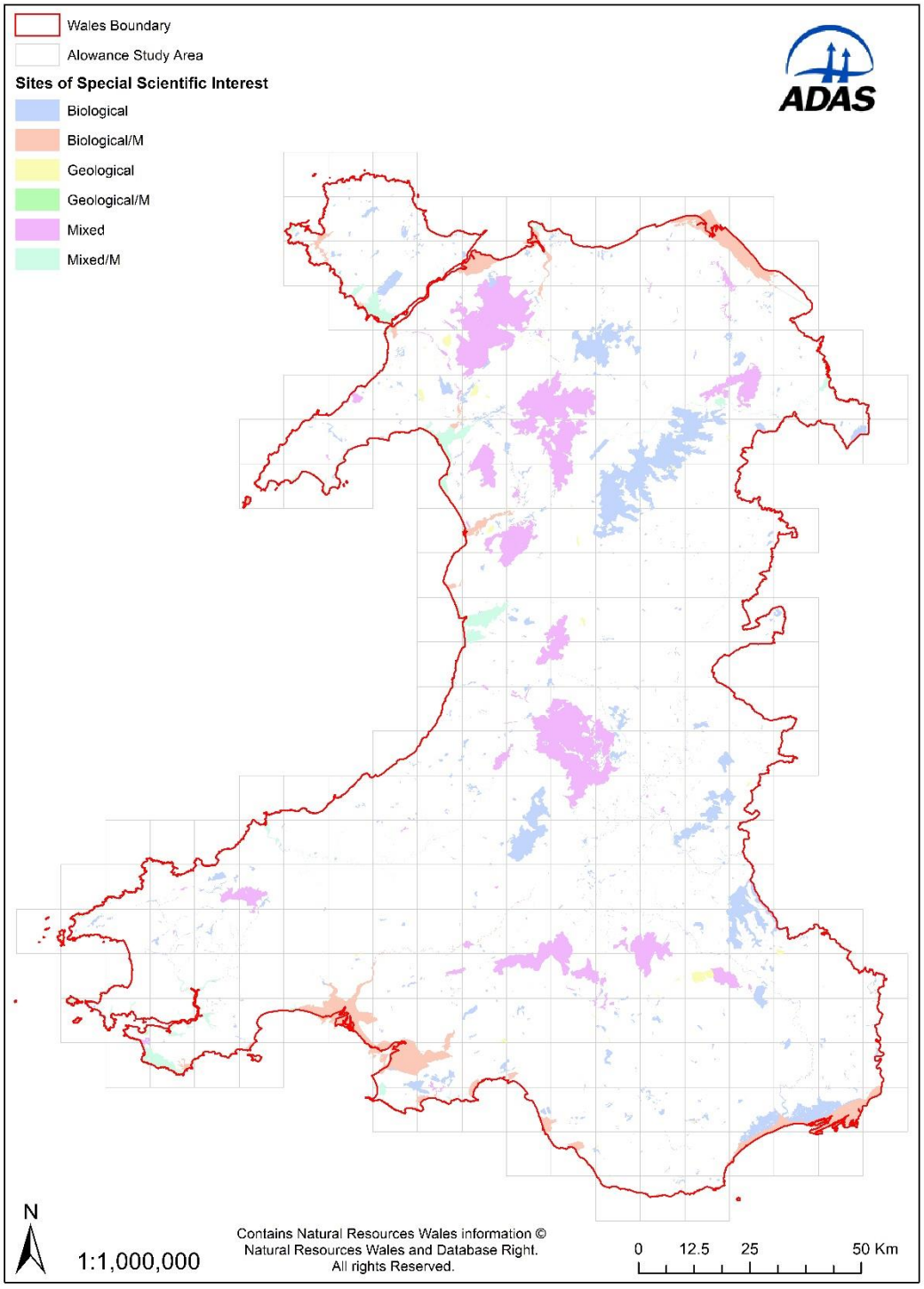
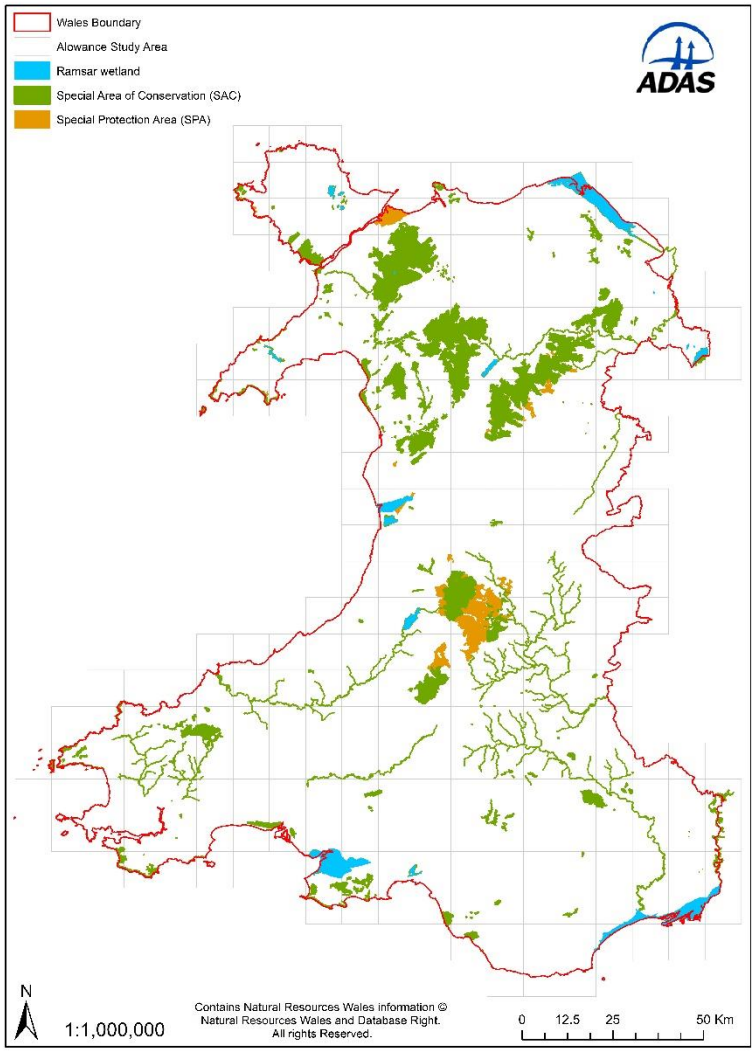


Figure 11. Sites of Special Scientific Interest (SSSIs).



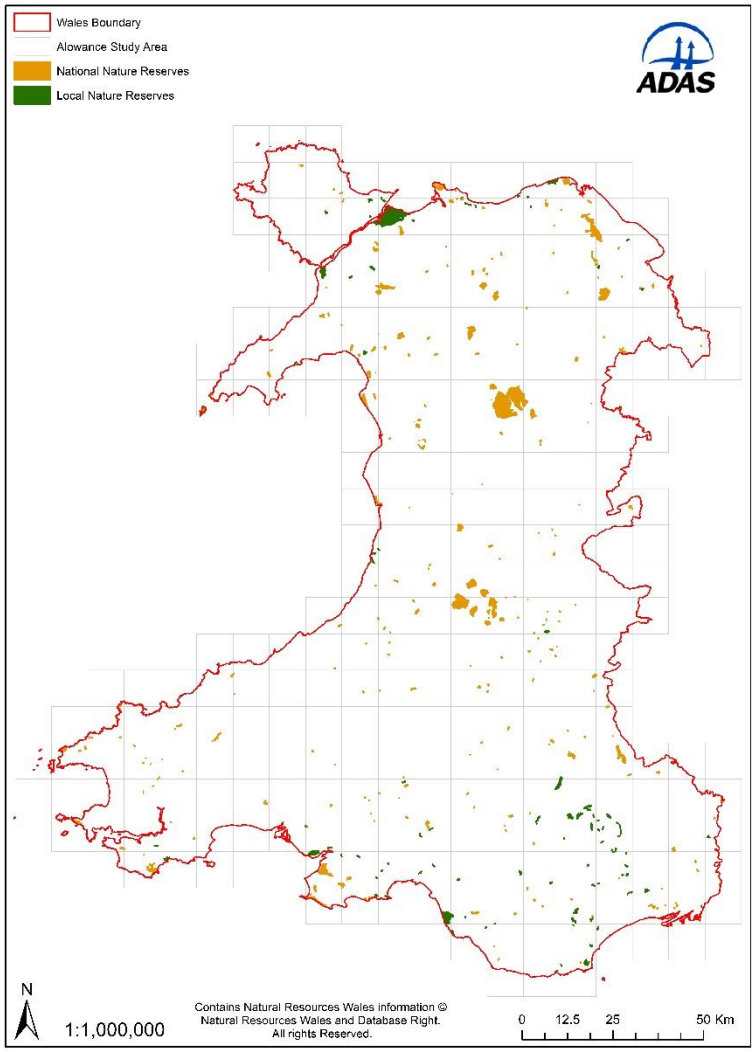


Figure 12. a) SPA, SAC and Ramsar sites and b). NNR and LNR

6.7 Environmental Impact Assessment

- Under Environment Impact Assessment (EIA) regulations most areas of priority habitat should not receive organic materials. The purpose of the EIA Regulations is to consider the effects of agricultural projects on the environment (e.g., habitats, species and historic features). Any farming operation undertaken to increase agricultural output from semi-natural land is subject to EIA regulation (Welsh Government, 2017). Specifically, projects that significantly change either the way land is farmed (so that it is used more intensively) or the species composition of the surface vegetation over the longer term.
- The Phase 1 Habitat Survey is the primary spatial dataset showing the distribution of semi-natural habitats across Wales. It was initiated in 1979 (upland survey) and completed in 1997 (lowland Phase 1); the primary aim was to identify candidate sites for designating as SSSIs (Lucas *et al.,* 2011).
- Although Phase 1 Habitat Survey data could potentially be used to exclude priority habitats identified under Phase I it was not used in this project. However, the majority (87%) of the datapoints identified in this dataset were already excluded because they intersected with other restrictions (e.g., SSSIs, steep slopes etc.).

6.8 Scheduled monuments

- Archaeological sites of national importance are given legal protection by being placed on a 'Schedule' of monuments. In Wales there are over 4,000 examples of Scheduled Monuments, which include Roman remains, burial mounds, castles, bridges, earthworks, the remains of deserted villages, industrial sites, and 20th century military complexes etc (Figure 13). The aim of scheduling is to preserve the archaeological evidence that survives within sites and monuments. This includes the physical fabric of the monument and any associated artefacts and environmental evidence, such as pollen or seeds.
- All organic materials were excluded from scheduled monument sites. Data on the location of scheduled monuments was obtained from DataMapWales (Scheduled monuments).

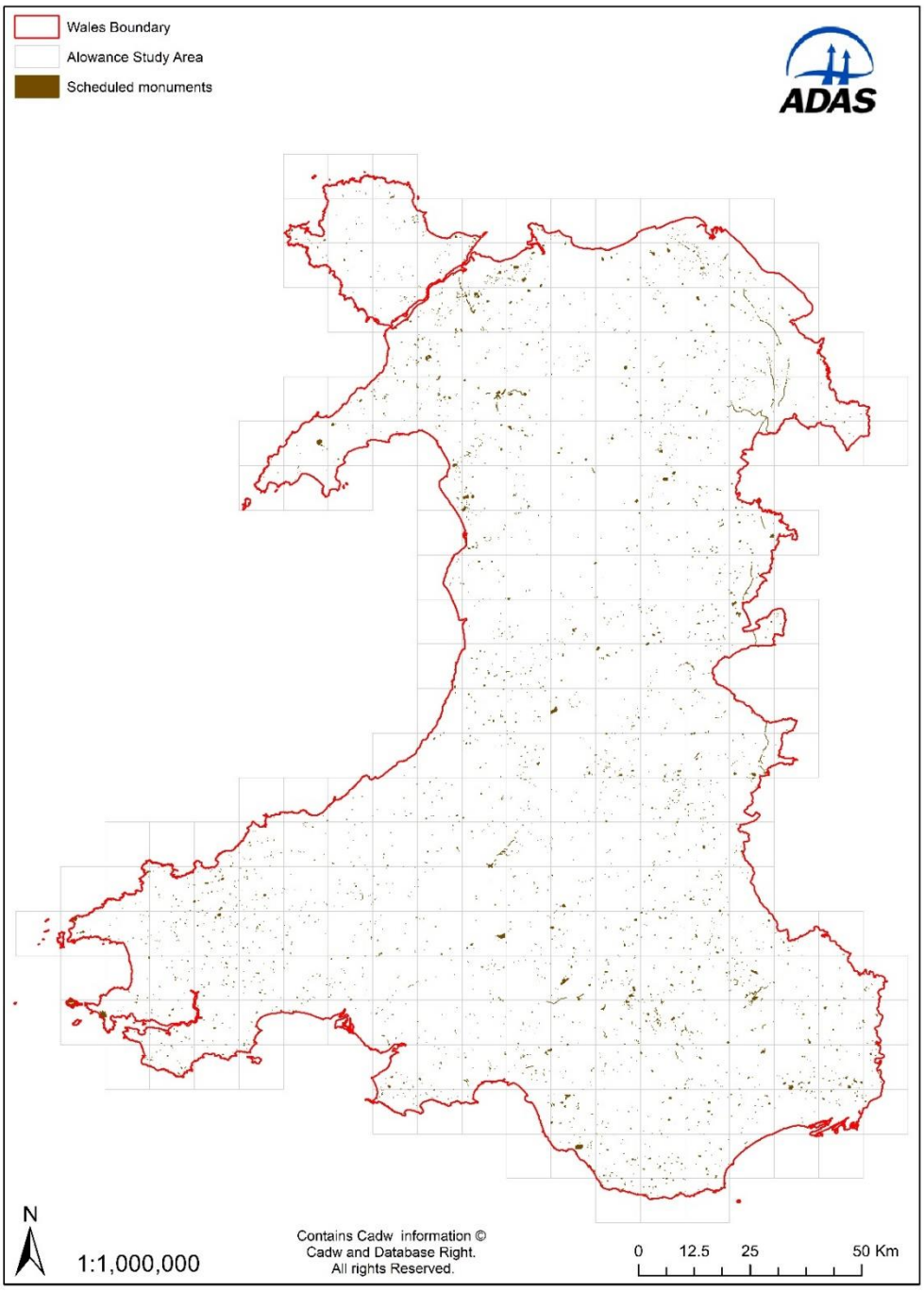


Figure 13. Scheduled monuments

6.9 Soil pH and metal concentrations

- Soil pH is a major factor affecting the availability of elements to plants. Crop damage from phytotoxic elements is more likely to occur on acid soils and metals generally become less available to plants as soil pH increases (except selenium and molybdenum where availability increases with pH).
- The Sludge (Use in Agriculture) Regulations (SI, 1989) and the Code of Practice for Agricultural Use of Sewage Sludge (Defra and Environment Agency, 2018) state that biosolids may not be applied to agricultural soil if the pH is <5. Also note that for certain wastes under deployment there are pH restrictions which will not allow the waste to be spread. For example, waste beer and wash water and waste from non-alcoholic drinks cannot be applied to land with pH <5.5 unless the acidity of the waste has previously been neutralised. Other pH restrictions apply to sludge from water clarification that has been treated with aluminium; sludge from alum water treatment should only be applied to soils of pH 6 and above.
- ALOWANCE uses pH data from the Representative Soil Sampling Scheme (RSSS), which measured the pH of agricultural soils in over 7,000 fields between 1969 and 2003; the dataset was interpolated to the 10 x 10 km grid cells, Figure 14.
- The RSSS sample farms were chosen to represent the major types of farming in England and Wales (based on a sub-sample of farms used in the British Survey of Fertiliser Practice). Where there was more than one RSSS data point in a 10 x 10 km grid cell, the average of the values was used. Where there was no RSSS data for a grid cell, the soil pH was assumed to be 6.5 for the purpose of assigning maximum permissible soil metal concentrations (Table 7), this is applicable to only 4% of grid squares (white squares in Figure 14). Note that the average pH for 1971, 1981, 1991 and 2001 (reported by the RSSS) was 6.67, 6.55, 6.52 and 6.70, respectively (the median was 6.55) (Oliver *et al.,* 2006). In each of these years the mean pH value was in the pH 6.0 to pH 7.0 class (in terms of metal limit values).
- The Sludge (Use in Agriculture) Regulations (SI, 1989) state that biosolids may only applied if soil heavy metal concentrations are below maximum permissible levels. The Regulations place legally binding limits on the amounts of Zinc (Zn), Cadmium (Cd), Lead (Pb), Copper (Cu), Mercury (Hg) and Nickel (Ni) in biosolids that can be applied annually and set out maximum soil metal concentrations above which biosolids cannot be applied. In the UK these are complemented by the Code of Practice for Agriculture Use of Sewage Sludge (which also includes a limit value for soil chromium) published in 1996 (DoE, 1996) and subsequently updated in 2018 (Defra and Environment Agency, 2018). ALOWANCE uses the soil heavy metal limits from the Code of Practice for Agriculture Use of Sewage Sludge (DoE, 1996) for arable soils. Note that for copper, nickel, mercury and chromium maximum permitted soil concentrations are higher for grassland than for arable soils.
- The soil metal limits in Table 7 were adopted in ALOWANCE to constrain the agricultural landbank available for biosolids (and other non-farm organic material) applications based on soil metal concentrations (Zn, Cu, Ni, Cr, Cd and Pb) measured in the National Soils Inventory (NSI), 1978-1982 (Rawlins *et al.,* 2012). Note that due to a lack of mercury data in the NSI dataset this metal was not used to constrain the landbank in ALOWANCE.

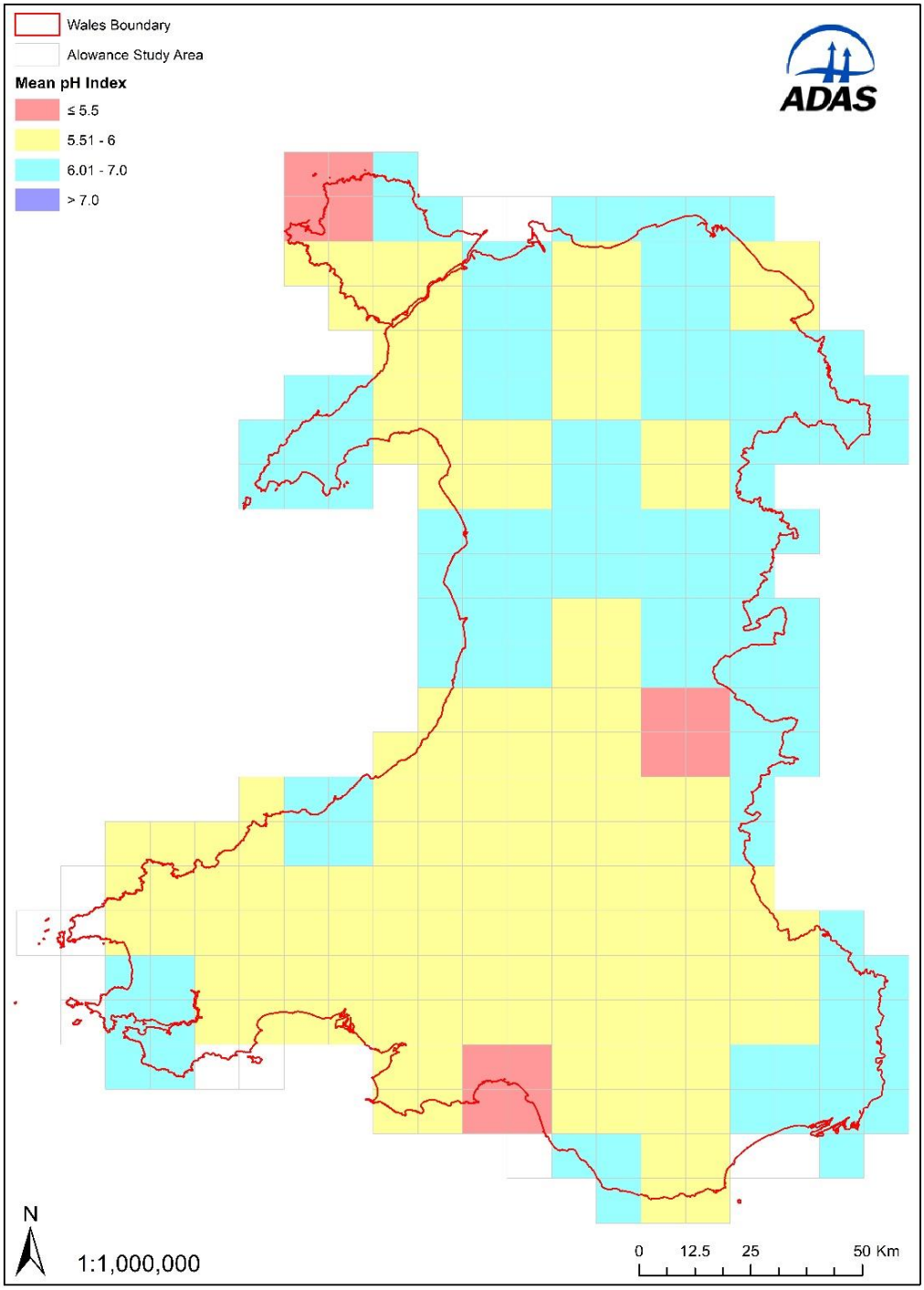


Figure 14. Soil pH. One grid square = 10,000 ha. (Source data: Representative Soil Sampling Scheme). White grid squares indicate areas where pH data was not available).

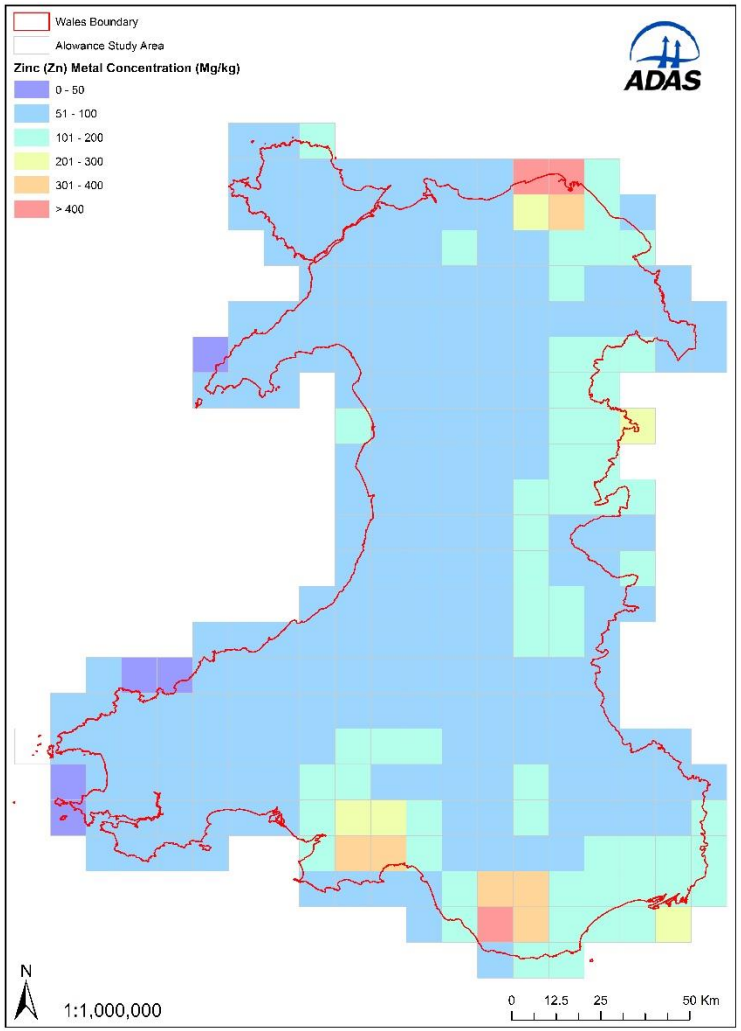
Table 7. Code of Practice for Agriculture Use of Sewage Sludge. Maximum permissible concentrations of potentially toxic elements (PTE) in arable soil after application of sewage sludge and maximum annual rates of addition to arable soils (sampled at 20 or 25 cm depths). Where values for grassland are different, they are noted in [square brackets].

Source: Department of the Environment, 1996. Defra and Environment Agency, 2018.

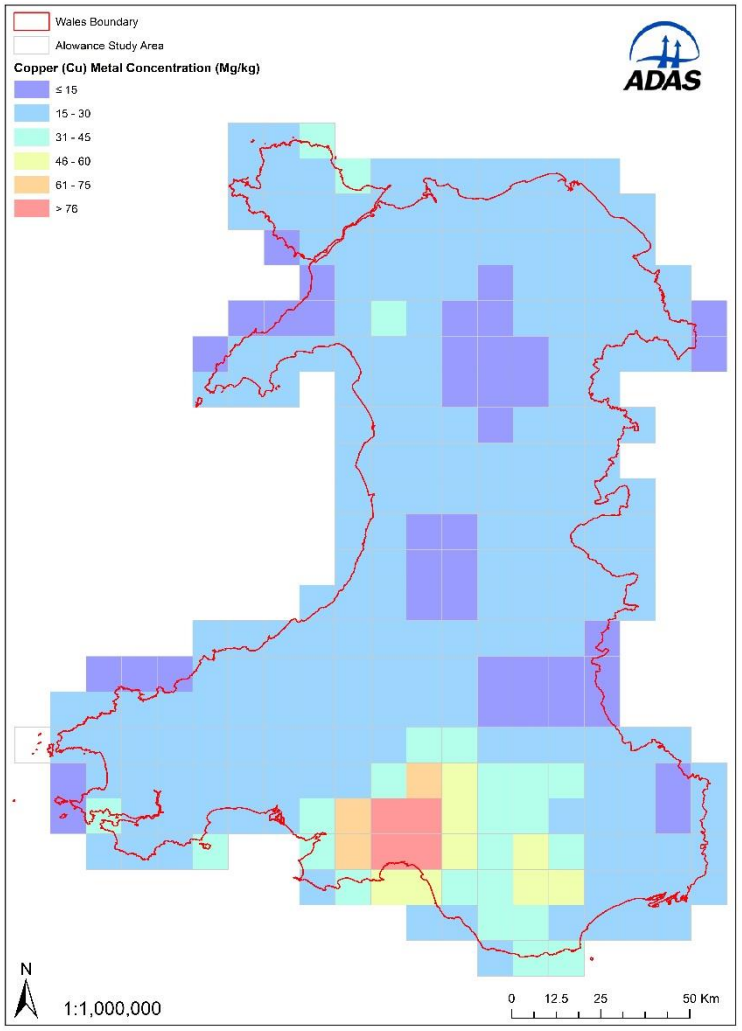
PTE	Maximum permissible concentration of PTE in soil (mg/kg dry soils)				Maximum permissible average annual rate of PTE addition over a 10-year period (kg/ha)
	pH 5 - <5.5	pH 5.5 - <6.0	pH 6.0 - 7.0	pH >7.0	
Zinc	200	200	200	300	15
Copper	80 [130]	100 [170]	135 [225]	200 [330]	7.5
Nickel	50 [80]	60 [100]	75 [125]	110 [180]	3
	For pH 5 and above				
Cadmium	3				0.15
Lead	300				15
Mercury	1 [1.5]				0.1
Chromium	400 [600]				15

- Data on soil metal concentrations are from the RSSS and the NSI, which are both comprehensive at a national scale (around 830 points in Wales from between 1969-2003 and 1983-1995, respectively). Whilst the datasets are old, they are the most up to date spatial point dataset available with comprehensive coverage at the national scale. The geochemical processes that affect the bedrock geology are one of the key factors influencing the natural concentrations of heavy metals in soils (Alloway, 2012, Crispo *et al.*, 2021). Consequently, the RSSS and NSI data although dated is still likely to be indicative of current metal concentrations.
- Soil concentrations of the metals included in ALOWANCE (i.e., Zn, Cu, Ni, Cd, Pb and chromium (Cr)) are illustrated in Figures 15 (a-f) for Wales. Orange or red colours indicate the areas of Wales where metal concentrations are highest. Note that each map has a different scale according to the range of metal concentrations found in Welsh soils.

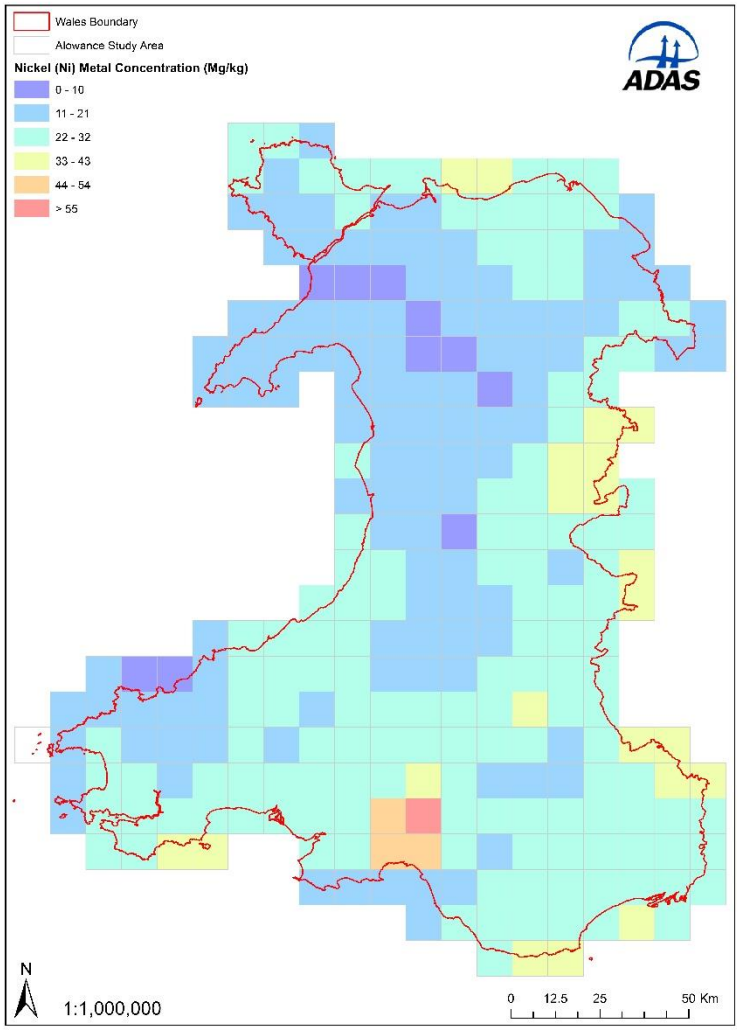
a) zinc



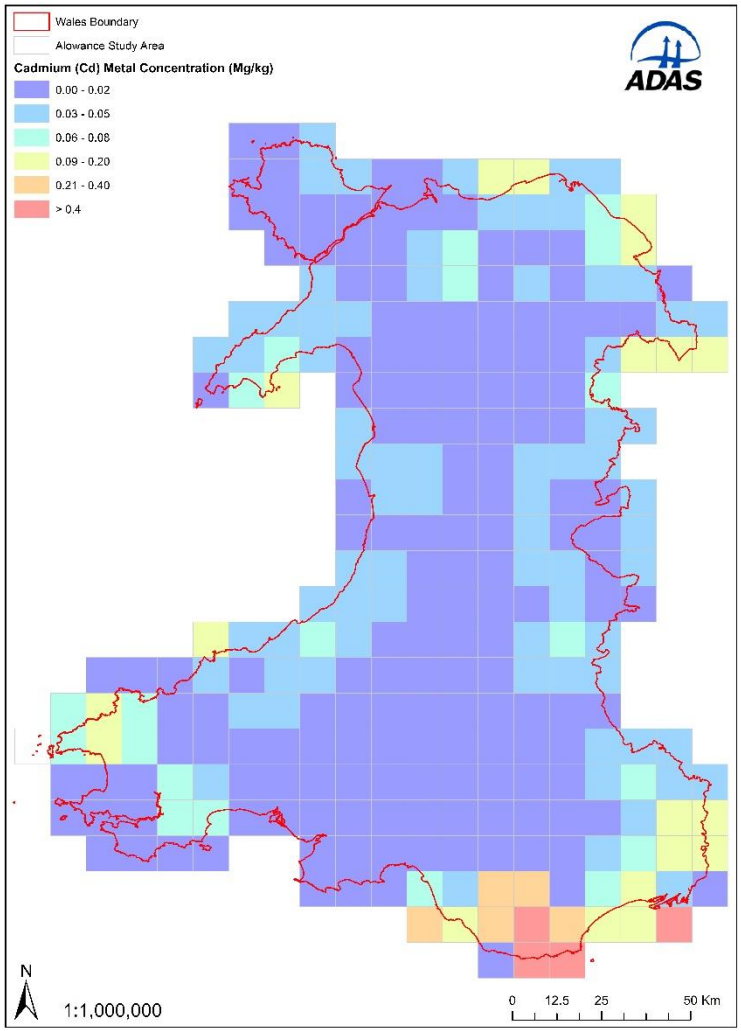
b) copper



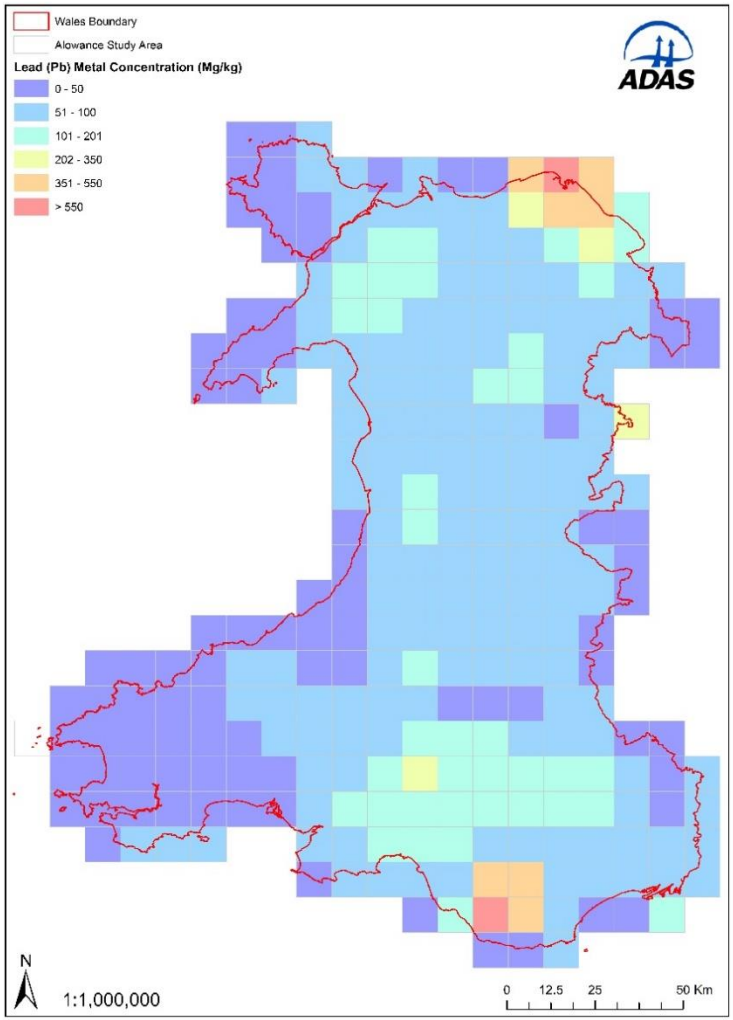
c) nickel



d) cadmium



e) lead



f) chromium

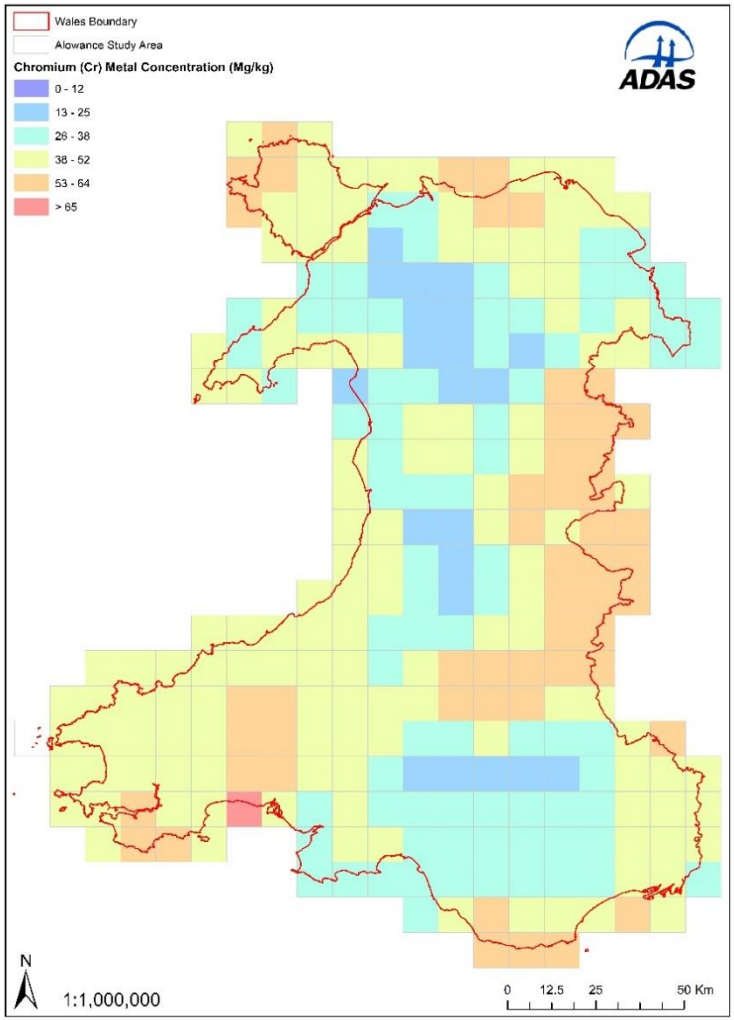


Figure 15. Soil metal concentrations (mg/kg dm), a) Zinc, b) copper, c) nickel, d) cadmium, e) lead and f) chromium. One grid square = 10,000 ha.

6.10 Glastir

- Data on land managed under Glastir Entry, Advanced, Commons and Organic was supplied by the Welsh Government from 2017-2022. The dataset included information on the option type and the location of the land under that management. Data from the most recent complete year (2021) was used in this project to identify areas under Glastir management. This was combined with information on organic material applications allowed under each Glastir Option to determine areas where organic materials could not be spread. Land managed under the various Glastir options is summarised in Table 8, below and in Sections 6.10.1 to 6.10.4.

Table 8. Total area of land in Wales under a Glastir agreement in 2021 and land area where organic materials cannot be applied.

Glastir	Total area (ha)	Area where organic materials cannot be applied (ha)
Entry	97,000	89,240
Advanced	134,000	120,600
Commons	116,000	116,000
Organic	77,000	Only organic FYM and slurry allowed

6.10.1 Glastir Entry

- Glastir Entry is comprised of three main components, 1) cross compliance, 2) the whole farm code (WFC) and 3) management options. The first two components are compulsory requirements. Glastir WFC is a set of compulsory requirements for land management and is split into a) rules applicable for all land and b) rules applicable for habitat land. Where land is classified as 'habitat land' typically there must be no application of slurry, FYM, sewage sludge or other off and on-farm wastes. Although note that some Glastir habitat options permit the spreading of FYM.
- According to data supplied by the Welsh Government there was *c*.97,000 ha of land in Glastir Entry in 2021 of which about 92% was in options that excluded or restricted manure applications. Land was managed under a variety of options, although two options made up almost 85% of the land area: Option 15. Grazed pasture – no inputs (16,250 ha) and Option 41a. Grazed open country (58,170 ha). Option 41a is only available on habitat land where according to Glastir guidance the following should not be applied "slurry, inorganic fertilisers, organic fertilisers, farmyard manure, basic slag, calcified seaweed, wastepaper sludge or other off and on-farm wastes" (Welsh Government, 2015).

6.10.2 Glastir Advanced

- Glastir Advanced is intended to deliver significant improvements to the environmental status of a range of habitats. Glastir Advanced comprises of four main components, 1) cross compliance, 2) the WFC, 3) management options and 4) advanced capital works. Several Glastir Advanced options prohibit or limit organic fertiliser additions.
- According to data supplied by the Welsh Government there was *c*.134,000 ha of land in Glastir Advanced in 2021 of which about 90% was in options that excluded or restricted manure applications. Land was managed under a variety of options, although two options made up 74% of the land area: Option 15. Grazed pasture – no inputs (31,026 ha) and Option 41a. Grazing management of open country (58,049 ha). Option 41a is only available on habitat land where according to Glastir guidance the following should not be applied "slurry, inorganic fertilisers,

organic fertilisers, farmyard manure, basic slag, calcified seaweed, wastepaper sludge or other off and on-farm wastes" (Welsh Government, 2019).

6.10.3 Glastir Commons

- Glastir Commons is available to applicants who hold rights on common land and have joined together to establish a Grazing Association. According to data supplied by the Welsh Government there was *c.*116,000 ha of land in Glastir Commons in 2021. Organic material application was not permitted on land under a Glastir Commons Agreement.

6.10.4 Glastir Organic

- Glastir Organic provides support to organic and "in-conversion" producers; land registered under Glastir Organic must be registered with an organic certification scheme. According to data supplied by the Welsh Government there was *c.*77,000 ha of land in Glastir Organic in 2021 (Figure 16). This represents 95% of the 81,3000 ha of organic land in Wales (Defra, 2021). Only applications of organic FYM and slurry were permitted on land under Glastir Organic; manure from non-organic sources and off-farm organic material applications were not permitted.

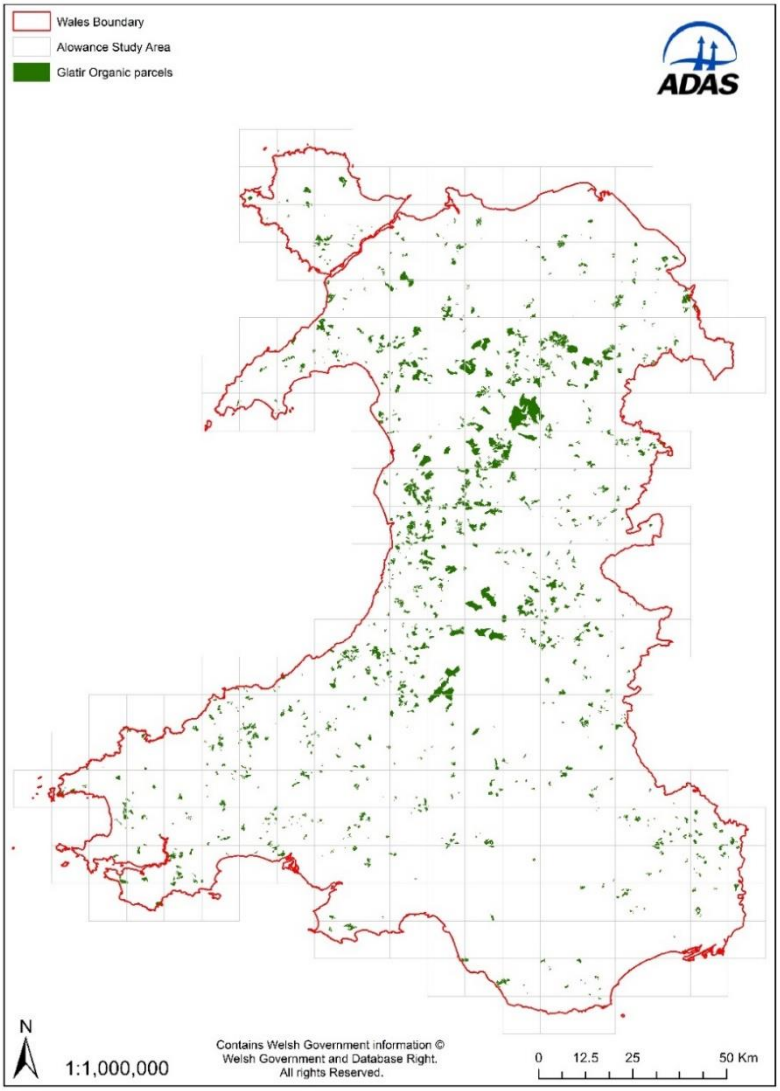


Figure 16. Location of Glastir Organic land

6.11 Soil phosphorus

- There are no specific regulatory limits on the application of P to agricultural land. However, where soil P is Index 3 or above (≥26 mg/l) COGAP recommends that "you should not apply more phosphorus than will be removed by the crops in the rotation". The P Index system is based on the likely response of the crop to a fresh application of phosphorus (indices range from 0 to 9). Index 0 soils are deficient, and it is likely that there would be an increase in yield by applying phosphorus. As the Index number increases the response to a fresh application of fertiliser decreases and for most soils growing arable, grassland and forage crops there would be no or very little response at Index 2 (some vegetables may respond to P applications at Index 3). This principle (i.e., to avoid building up or maintenance above the target Index) underpins the guidance in RB209 for P applications (AHDB, 2021).
- Also, EPR guidance, highlights the risk of applications to soil at or above P Index 3 (additional risk assessment is also required). And, to comply with the Biosolids Assurance Scheme biosolids applications must follow guidance in the Biosolids Nutrient Management Matrix which limits applications based on soil P Index (as well as biosolids N content), (BAS, 2020).
- ALOWANCE includes data on soil phosphorus content from the RSSS and the NSI, which are both comprehensive at a national scale (around 830 points in Wales) but may be considered out of date (with data available from between 1969-2003 and 1983-1995, respectively). However, although the datasets are old, they are the best spatial point datasets available with comprehensive coverage at the national scale. In comparison, Glastir Monitoring and Evaluation Programme data is more current (2013-2016) but only has around 140 unique datapoints for soil P. There is also very limited data available from the Countryside Survey for 2019 (from <10 sites in Wales). The lack of current data on a national scale indicates the clear need for more publicly available data on soil P for Wales.

7 Limitations, assumptions and caveats

- The project has estimated the available landbank for Wales based on physical and practical constraints, and current legislative restrictions on organic material recycling using the GIS-based tool ALOWANCE (Agricultural land and organic waste: a national capacity estimator). The tool was designed to indicate the available landbank at a national scale or at local scale, but it was not designed for use at the field scale.
- ALOWANCE uses a rule-based algorithm (derived from the restrictions and constraints) to decide how and where organic materials should be allocated to the available agricultural landbank capacity.
- Table 9 below summarises the limitations of this approach and lists the assumptions that have been made in estimating the final landbank for organic material recycling for Wales.

Table 9. Limitations and assumptions used in estimating the available landbank for Wales

Limitation/assumptions	Details and influence of limitation
Data resolution	ALOWANCE is designed to give an overview of landbank availability (a 10 x 10 km spatial representation of land use). It is not designed to make decisions at the field scale.
Average conditions	ALOWANCE predictions are based on average conditions for a 10 km by 10 km grid square and do not necessarily reflect the physical restrictions for an individual field within that grid square.
Uncertainty/variability is not captured	A single value for landbank is calculated.
Social and economic factors are not included	ALOWANCE will estimate the maximum available landbank Factors such as farmer, retailer and public acceptance will influence land availability for organic materials. For example, some farmers will be unwilling to apply biosolids due to perceptions of odour or restrictions imposed by, for example, farm assurance schemes. It is assumed that farmers apply N at the maximum permitted rate in accordance with legislation. Where the actual rate application rate is lower more landbank is required for the same amount of material.
Weather/climate factors not included	Closed periods, flooding, weather conditions etc.
Livestock numbers and cropping	Until the mid-1990s the June Survey of Agriculture and Horticulture survey was a census of all farms. However, it is now a survey of a proportion of farms annually. In Wales about 11,000 farms are included in the survey annually: around 30% of registered holdings. Data for non-surveyed farms is interpolated from the most recent data for those farms using the trends on comparable farms. Data is collected at the level of the individual farm, however, although the total area of crops (or animals on a farm) is known the precise location where crops are grown (or animals graze) is not. Geographic estimates are made based on the farm address or known digital field boundaries. Clearly this is an estimate and a simplification of reality
Nitrogen production of livestock,	ALOWANCE assumed nitrogen production of each livestock type based on literature data. The values have been corrected for occupancy and can be used as direct multipliers with animal numbers from the Agricultural Survey. The correction accounts for the fact that some livestock, e.g., broilers, may have an occupancy on the farm of less than 365 days.

Limitation/assumptions	Details and influence of limitation
Handled/deposited manure	Based on literature values, 38% of dairy cattle excreta was estimated to be deposited during grazing over the course of a year with the remaining 62% as handled manure. ALOWANCE also includes assumptions for other cattle (i.e., dairy cattle not in-milk and beef cattle, 35-45% handled manure) and sheep (5% handled manure). For pigs and poultry (other than free range layers), it is assumed that 100% of manure comes from housed livestock (i.e., is handled manure).
Farmyard manure or slurry	The FYM/slurry split in ALOWANCE is based on published data on the proportion of manure excreted as slurry or FYM. The proportion of excreta as slurry is around 70% for dairy cattle, 20% for beef cattle, 75% for breeding gilts/sows and 35% for growing/fattening pigs.
Assumed nitrogen content for organic materials	Data on the N content of organic materials applied to land (and hence the landbank required) is based on 'typical' values from the Nutrient Management Guide RB209 (AHDB, 2021). Information on the quantity produced for land spreading (e.g., biosolids or compost) was combined with data on the 'typical' N content of the materials, to calculate the N loading to agricultural land in each 10 x 10 km grid square. In practice, materials will have a wide range of N concentrations based on factors such as feedstock type. However, it is not practicable to use measured values for N concentrations; there is currently no central resource for collating nutrient concentrations of organic materials.
Digestate	To avoid double counting digestate produced from slurry feedstocks was not included in the total applied to land (it was assumed that this had been accounted for in livestock slurry production). Note that only around 4% of the digestate feedstock in Wales was slurry.
Permitted wastes	Because the amount of material of each type applied under each deployment was not known it was assumed that the total deployment tonnage was split equally between the material types. Typical nutrient content of waste materials that are commonly recovered to land are included in RB209 (AHDB, 2021) and were used to calculate the N content of the materials described in the mobile plant deployments.
Private water supplies	The datasets used in this project do not identify private water supplies, so it was not possible to exclude areas around these sources from the available landbank.

Limitation/assumptions	Details and influence of limitation
	In 2021 around 2% (*c.*68,000 people) of the population in Wales (3.2 million people) used potable water from 14,723 private supplies. Based on an exclusion zone of 50 m for each private supplies in Wales an additional 11,562 ha would be excluded from the landbank (equating to up to 2.5% of the landbank remaining (579,000 ha) after the other exclusions applied in this report had been applied).
Protected sites	The scope of this project does not permit specific conditions to be applied to individual designated sites. It was assumed that only low readily available nitrogen manure (FYM) could be applied to these sites and that high readily available nitrogen-RAN manures (e.g., slurry and poultry manure) and off-site materials (i.e., compost, digestate, biosolids and permitted wastes) were not applied.
Soil pH	Where there was more than one RSSS data point for soil pH in a 10 x 10 km grid cell, the average of the values was used. Where there was no RSSS data for a grid cell, the soil pH was assumed to be 6.5 for the purpose of assigning maximum permissible soil metal concentrations. This assumption is reasonable given that the average pH for 1971, 1981, 1991 and 2001 was in the pH 6.0 to pH 7.0 class (in terms of metal limit values).
Soil heavy metals	ALOWANCE uses the soil heavy metal limits from the Code of Practice for Agriculture Use of Sewage Sludge (DoE, 1996) for arable soils. Note that for copper, nickel, mercury and chromium maximum permitted soil concentrations are higher for grassland than for arable soils. Using the arable values for grassland is likely to result in a slight underestimate of the available landbank.
Soil phosphorus	ALOWANCE includes data on soil phosphorus content from the RSSS and the NSI, which are both comprehensive at a national scale (around 830 points in Wales) but maybe considered out of date (with data available from between 1969-2003 and 1983-1995, respectively). However, although the datasets are old, they are the best spatial point datasets available with comprehensive coverage at the national scale. In comparison, Glastir Monitoring and Evaluation Programme data is more current (2013-2016) but only has around 140 unique datapoints for soil P. There is also very limited data available from the Countryside Survey for 2019 (from <10 sites in Wales).

8 Final landbank

- In 2021 there was *c*.1.8 million hectares of agricultural land in Wales which was reduced to *c*.1.4 million hectares (the potential landbank) after excluding, woodland, 'other land' on farms and rough grazing (land areas from the Survey of agriculture and horticulture, June 2021, Welsh Government, 2021), Table 10.
- In line with current regulatory guidance the available landbank in Wales was estimated using the ALOWANCE model which is based on restrictions on nitrogen loading rates (as well as physical, practical and legislative constraints).
- Accounting for current livestock manure production (removing 550,000 ha), exclusions because of physical, legislative and land use restrictions (removing 252,000 ha), and non-farm organic materials (removing 18,000 ha) reduced the landbank by 820,000 hectares. Subtracting this area from the potential landbank for organic materials (1.4 million hectares) gave a final estimate of the available landbank for 'new' (i.e., additional quantities of digestate, biosolids, compost or other new organic materials) organic materials of *c*.579,000 hectares, Table 10.

Table 10. ALOWANCE estimated landbank in Wales (thousand hectares)

Estimated landbank in Wales	**Area (thousand hectares)**	**Notes**
Theoretical landbank	1800	Agricultural area
Potential landbank for organic materials	1400	After removing woodland, other land on farms and rough grazing
Landbank area removed to account for:		
1. Livestock manure N production	550	Excreted whilst grazing and handled/spread manure
2. Physical/legislative/land use restrictions	252	Including restrictions relating to slopes, proximity to watercourses, soil pH and metal concentrations (not applicable to livestock manures), restrictions in SSSIs etc. and legislative limits.
3. Current sources of organic materials	18	Biosolids, compost, digestate and waste applied under EPR.
Total area removed	820	
Estimated landbank for additional organic materials	**579**	Remaining landbank after removing land where organic materials cannot be applied and after accounting for current requirements for landbank (1-3, above).
Landbank area removed by P restrictions		
Soil phosphorus (≥ P index 3)	126	Applications only allowed at P Indices 0, 1 and 2
Estimated landbank for additional organic materials (with additional P restriction)	**453**	

- The estimated landbank available for additional organic materials in each 10 x 10 km grid square in Wales (579,000 ha) is shown in Figure 17, below.

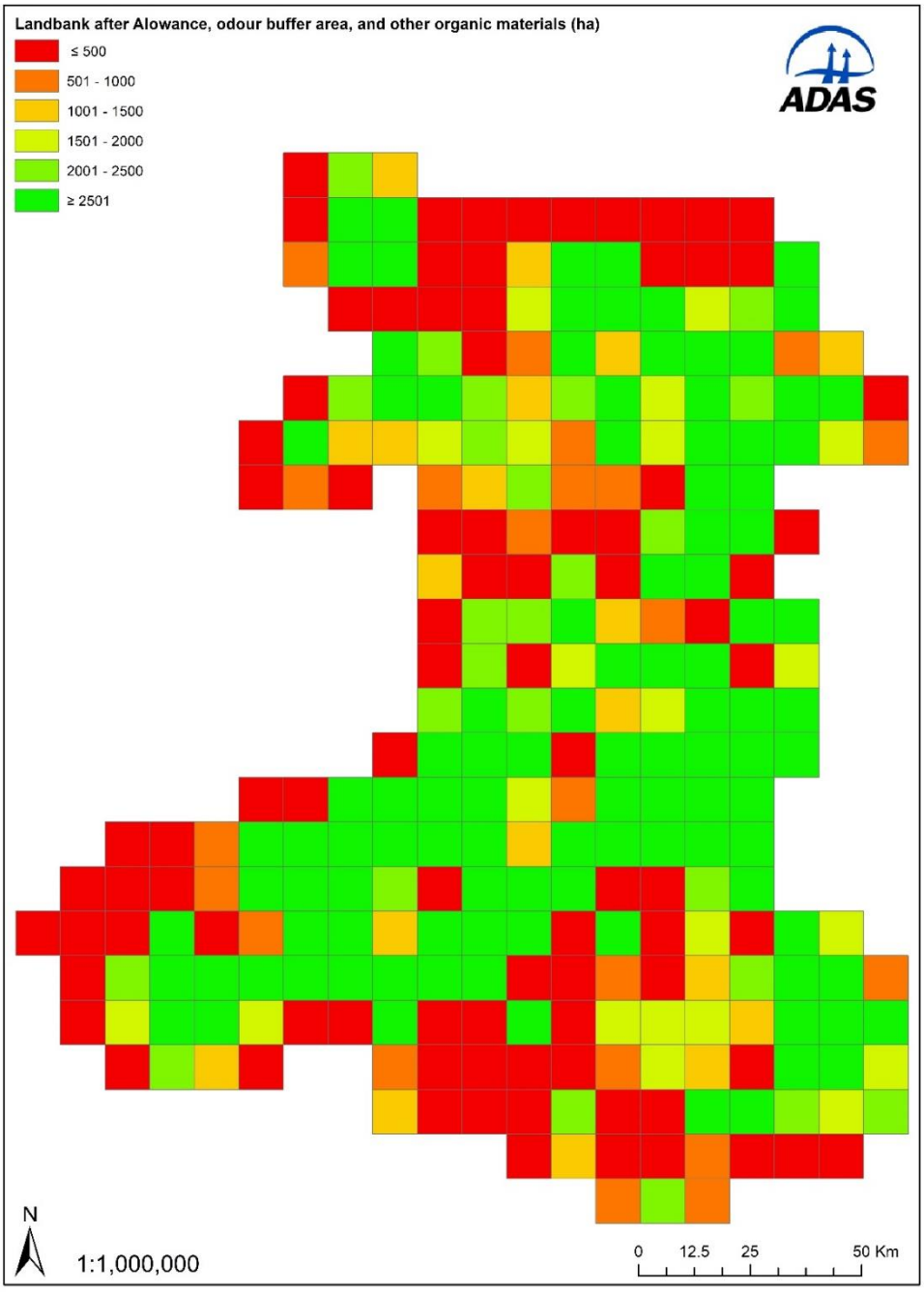


Figure 17. Final landbank (ha). No application to slope >12°, 10 m buffer around surface water and 50 m around boreholes, springs and wells, 50 m urban/odour buffer, organic material restrictions in SPZ1, designated sites, land under Glastir management and according to soil pH and metal concentrations. Accounting for applications of livestock manures, compost, digestate, biosolids and wastes applied under Environmental Permitting Regulations. Total available landbank is 579,000 ha. One grid square = 10,000 ha.

- Figure 17 shows that in some parts of the country (e.g., south Wales, north Wales, and Pembrokeshire) the landbank is already under 'pressure' and transport of any future 'new' sources of organic materials away from these areas may be required. Where less than 5% of the land in a 10 km x 10 km square is suitable for organic material application (i.e., the red grid squares in Figure 17) then it can be considered that there is very limited capacity for additional organic material use in that square. Where more than 25% of the land is suitable (i.e., the bright green squares in Figure 17) it can be assumed that there is significant capacity for additional organic material use in that square.
- Figure 18 is the same map as Figure 17 (landbank 579,000 ha) but also shows the point sources of non-organic materials (biosolids, compost, digestate and permitted waste) in a series of circles; small circle: landbank required <500 ha, medium circles: landbank required 501-1,000 ha and large circles: landbank required >1,001 ha. The location of the point source is based on the postcode of the compost or digestate plant, wastewater treatment plant or deployment. Although there are point sources throughout Wales, areas with several point sources include Anglesey, some parts of northeast Wales (e.g., Denbighshire, Flintshire and Wrexham), Monmouthshire and Pembrokeshire.
- Pembrokeshire and South Wales (particularly Monmouthshire and the Vale of Glamorgan) are some of the main arable regions of Wales, together they account for *c.*50% of the area of cereals grown in Wales and *c.*70% of the potato area. In some of these areas there is very limited capacity for additional organic material use as there is less than 5% of available landbank. Arable areas are more likely than grassland to receive applications of non-farm organic materials – for example The British survey of fertiliser practice (BSFP) notes that *c.*85% of biosolids are applied to arable crops and 65% of other non-farm organic materials. In comparison, in many areas of Carmarthenshire and Powys the available landbank in many of the 10 x 10 km grid squares is >2,500 ha (more than 25% of the agricultural area) indicating a greater potential for new organic material applications, although particularly in Carmarthenshire there is very little arable land.
- Organic material applications have not been routinely limited according to soil P in this project; the estimated landbank for additional organic materials (579,000 ha) has been based on current legislation on application rates (which focus on limiting nitrogen applications). However, future legislative changes could include controls on phosphorus applications, for example, matching P offtakes to inputs or excluding applications based on soil P concentrations. To provide an indication of the effect of potential P limited applications ALOWANCE was used to model a scenario where organic material applications were restricted to soils below P Index 3 (i.e., <26 mg/l Olsen extractable P). When this additional restriction was applied the landbank was reduced by a further 126,400 hectares giving a total landbank available for additional organic materials of 452,600 hectares (i.e., 33% of the potential landbank of *c.*1.4 million ha), Figure 19. Under this scenario, the landbank in Pembrokeshire and South Wales was further reduced and in some areas around Conwy, Denbighshire, Flintshire and Wrexham it was reduced to less than 5% of the total landbank in a 10 x 10 km grid square.

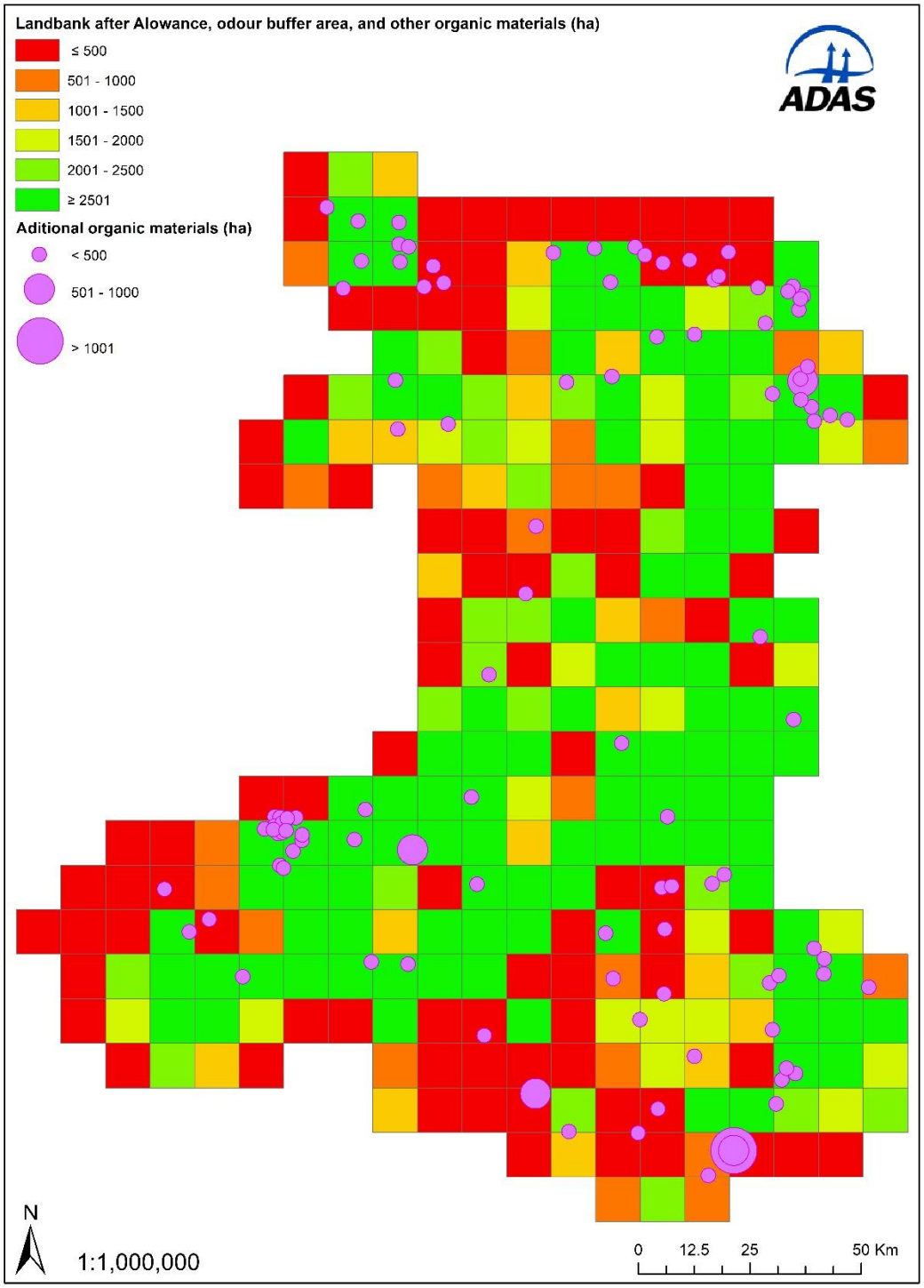


Figure 18. Final landbank (ha) and non-farm organic materials (compost, digestate, biosolids and material applied under EPR). No application to slope >12°, 10 m buffer around surface water and 50 m around boreholes, springs and wells, 50 m urban/odour buffer, organic material restrictions in SPZ1, designated sites, land under Glastir management and according to soil pH and metal concentrations. Accounting for applications of livestock manures, compost, digestate, biosolids and wastes applied under Environmental Permitting Regulations. Total available landbank is 579,000 ha. One grid square = 10,000 ha.

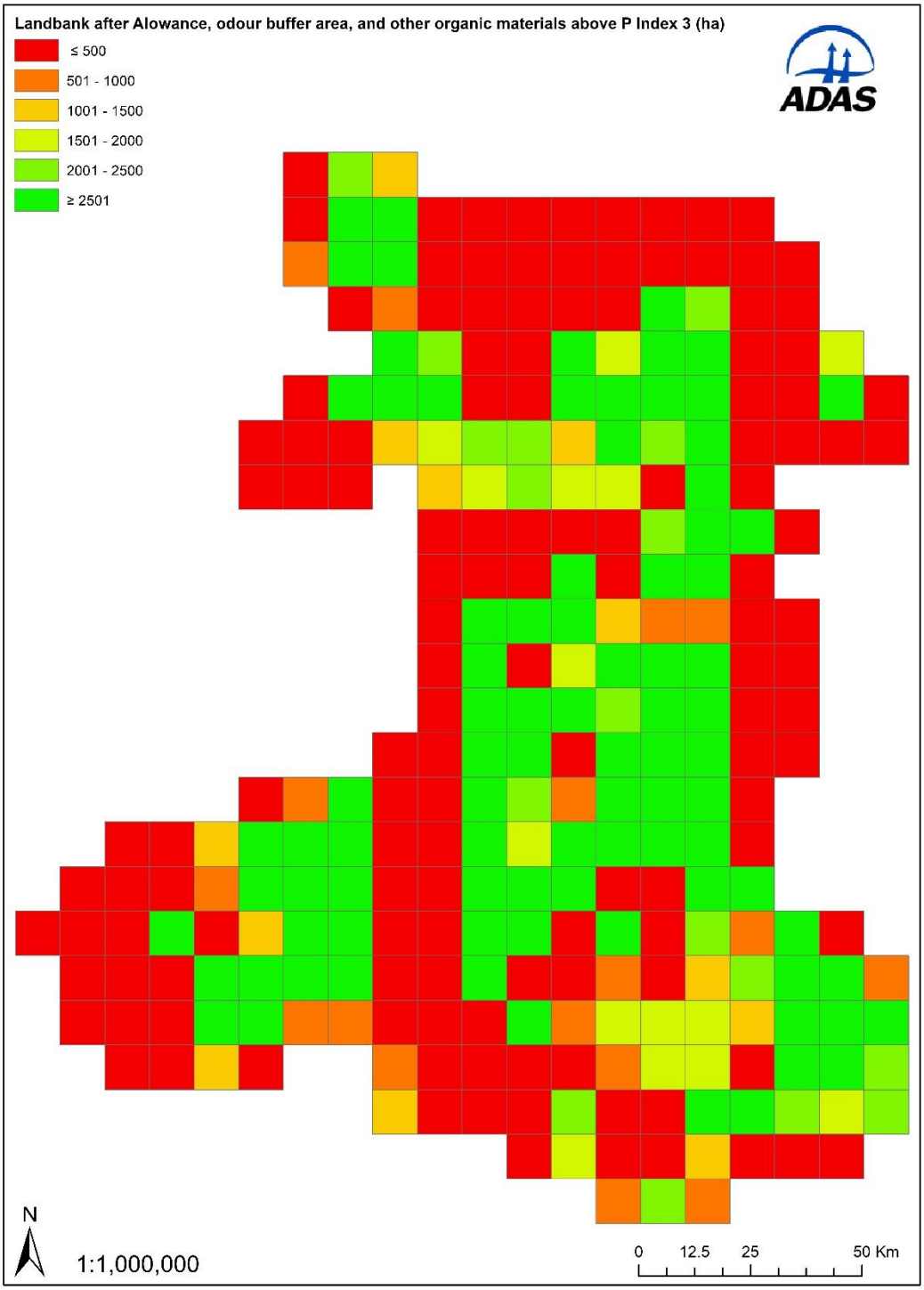


Figure 19. Final landbank (ha). No application to slope >12°, 10 m buffer around surface water and 50 m around boreholes, springs and wells, 50 m urban/odour buffer, organic material restrictions in SPZ1, designated sites, land under Glastir management and according to soil pH and metal concentrations. No applications to land ≥P Index 3. Accounting for applications of livestock manures, compost, digestate, biosolids and wastes applied under Environmental Permitting Regulations. Total available landbank is 452,600 ha. One grid square = 10,000 ha.

9 Conclusions

- This project has used currently available evidence to investigate the distribution and size of the landbank available for organic materials in Wales using the ALOWANCE (Agricultural Land: A National Capacity Estimator) tool (Nicholson *et al*., 2012). ALOWANCE calculates the agricultural landbank available for organic materials from farm and non-farm sources, based on nitrogen loading rates, the physical and soil constraints of the landscape (including factors such as soil pH, heavy metal content and topography) and legislative restrictions. This is in line with current regulatory controls on organic materials in Wales, The Water Resources (Control of Agricultural Pollution) (Wales) Regulations 2021, which are designed to control nitrogen losses to water.

9.1 Potential landbank

- In 2021 there was *c*.1.8 million hectares of agricultural land in Wales. After removing land which was unsuitable for organic material applications (i.e., woodland, 'other land' on farms and rough grazing) the landbank was reduced to *c.*1.4 million hectares (land areas from the Survey of agriculture and horticulture, June 2021, Welsh Government, 2021). This is the potential landbank for organic material applications in Wales.

9.2 Organic materials

- Based on data collated for this project an estimated 10 million tonnes of organic materials (i.e., livestock manure, compost, digestate, biosolids and material applied under permit) were applied to agricultural land in Wales in 2021. Most of the organic materials (88%) were livestock manures including handled manure from housed livestock subsequently spread to land and excreta directly deposited by grazing animals.

9.3 Available landbank for new organic materials

- The potential landbank (prior to any organic material additions) was calculated by considering the proportion of each 10 x 10 km grid cell that was agricultural land, and within this how much was excluded by physical or legislative restrictions.
- In this project the following constraints, limits or exclusions were applied:
    - Handled manure or other organic materials were not applied where slopes >12°.
    - Handled materials were not spread within 10 m of surface water (includes all rivers, streams, ditches, drains, cuts, culverts, dikes, sluices, sewers, and passages through which water flows, except mains and other pipes) or within 50 m of a spring, well or borehole.
    - SPZ1 areas were excluded from the agricultural landbank available for organic material recycling.
    - Designated sites (e.g., SSSIs, NNRs, LNRs etc.): it was assumed that only low readily available nitrogen manure (FYM) could be applied to these sites and that high readily available nitrogen-RAN manures (e.g., slurry and poultry manure) and off-site materials (i.e., compost, digestate, biosolids and permitted wastes) were excluded
    - All organic materials were excluded from scheduled monument sites.
    - Soil pH: biosolids and other non-farm materials were excluded where soil pH <5
    - Soil metal limits: biosolids (and other non-farm organic material) were excluded where soil heavy metal concentrations were above maximum permissible levels.
    - Glastir Entry, Advanced, Commons and Organic: applications were restricted according to management option criteria.

    - Peas and beans: applications were not permitted (no N requirement)
    - Ready to eat crops: applications were not permitted to these crops.
    - The Water Resources (Control of Agricultural Pollution) (Wales) Regulations 2021: nitrogen limits (whole farm 170 kg N/ha; individual hectare 250 kg N/ha)
- After accounting for physical and land use restrictions (which removed 252,000 ha) the landbank required to account for current livestock N production and other organic materials was removed from the available landbank (568,000 ha). This gave a final estimate of the available landbank for 'new' (i.e., additional quantities of digestate, biosolids, compost or other new organic materials) organic materials of *c*.579,000 hectares, equating to 41% of the potential landbank.
- The landbank available for new organic materials (*c*.579.000 ha) is larger than that currently used by livestock manures and organic materials (*c*.568,000 ha). This suggests that there is sufficient landbank for additional organic material applications to land in Wales. However, it should be noted that in some parts of the country (e.g., south Wales, north Wales, and Pembrokeshire) the landbank is already under 'pressure' (i.e., less than 5% of the land in a 10 km x 10 km square is available for organic material application) and transport of any future 'new' sources of organic materials away from these areas may be required. In comparison, in many areas of Carmarthenshire and Powys the available landbank in many of the 10 x 10 km grid squares is >2,500 ha (more than 25% of the agricultural area) indicating a greater potential for new organic material applications in these areas.
- To provide an indication of the effect of potential P limited applications ALOWANCE was used to model a scenario where organic material applications were restricted to soils below P Index 3 (i.e., <26 mg/l Olsen extractable P). When this additional restriction was applied the landbank was reduced by a further 126,400 hectares giving a total landbank available for new organic materials of 452,600 hectares (i.e., 33% of the potential landbank of *c*.1.4 million ha).

10 References

ADAS, North Wyke Research and Imperial College Consultants Ltd (2007). Agricultural land and organic waste – a national capacity estimator (ALOWANCE). Defra Project Code ES0128.

ADAS and North Wyke (2008). *The National Inventory and Map of Livestock Manure Loadings to Agricultural Land: MANURES-GIS.* Defra Report WQ103.

AHDB (2021). *Nutrient Management Guide (RB209)*. Agriculture and Horticulture Development Board

Alloway, B. (2012). *Heavy metals in soils trace metals and metalloids in soils and their bioavailability.* In: Heavy metals in soils: trace metals and metalloids in soils and their bioavailability

Armstrong, E. (2016). *Research Briefing: The Farming Sector in Wales*. National Assembly for Wales Research Service.

BAS (2020). *Biosolids Assurance Scheme*. The BAS Standard. Issue number 5. Assured Biosolids Limited

Crispo, M., Dobson, M.C., Blevins, R.S., Meredith, W. and Lake, J.A. (2021). Heavy metals and metalloids concentrations across UK urban horticultural soils and the factors influencing their bioavailability to food crops. *Environmental Pollution*, 288, 117960.

BSFP (2021). The British survey of fertiliser practice fertiliser use on farm crops for crop year 2020. Defra.

Defra (2021). *Organic farming statistics United Kingdom 2021*. Department for Environment & Rural Affairs.

Defra and Environment Agency (2018). *Sewage sludge in agriculture: code of practice for England, Wales and Northern Ireland*. https://www.gov.uk/government/publications/sewage-sludge-in-agriculture-code-of-practice/sewage-sludge-in-agriculture-code-of-practice-for-england-wales-and-northern-ireland.

Drinking Water Inspectorate (2022). *Drinking water 2021. The Chief Inspector's report for drinking water in Wales.* DWI

Environment Agency (2019). *Manual for the protection of Groundwater Source Protection Zones. March 2019.* Environment Agency

Farr, G., Ander, E.L., James, K., Kibble, A., Jones, D.A. and Jones, C. (2022). Revealing the importance of groundwater for potable private supplies in Wales. *Quarterly Journal of Engineering Geology and Hydrogeology*, 55, qjegh2021-078

FSA (2009). *Managing farm manures for food safety. Guidelines for growers to reduce the risks of microbiological contamination of ready-to-eat crop*. Food Standards Agency.

Keay, C.A. and Hannam, J.A. (2020). *The effect of climate change on Agricultural Land Classification (ALC) in Wales*. Capability, Suitability & Climate Programme Welsh Government Report.

Lucas, R., Medcalf, K., Brown, A., Bunting, P., Breyer, J., Clewley, D., Keyworth, S. and Blackmore, P. (2011). Updating the Phase I habitat map of Wales, UK, using satellite sensor data. *ISPRS Journal of Photogrammetry and Remote Sensing*, 66, 81-102.

Nicholson, F.A., Humphries, S., Anthony, S.G., Smith, S.R., Chadwick, D. and Chambers, B.J. (2012). A software tool for estimating the capacity of agricultural land in England and Wales for recycling organic materials (ALOWANCE). *Soil Use and Management*, 28, 307-317.

NRW (2016). *Standard rules SR2010 No4 v6.1. Mobile plant for landspreading (land treatment resulting in benefit to agriculture or ecological improvement). Chapter 4, The Environmental Permitting (England and Wales) Regulations 2016*. Natural Resources Wales.

NRW (2017). *How to comply with your landspreading permit. TGN 8.01*. Version 5. Natural Resources Wales

Rawlins, B.G., McGrath, S.P., Scheib, A.J., Breward, N., Cave, M., Lister, T.R., Ingham, M., Gowing, C. and Carter, S. (2012). *The advanced soil geochemical atlas of England and Wales*. British Geological Survey, Keyworth.

REAL (2021). *Compost/Biofertiliser Certification Schemes. Annual Report 2020*. Renewable Energy Assurance Ltd.

Russell, S., Blackstock, T., Christie, M., Clarke, M., Davies, K., Duigan, C., Durance, I., Elliot, R., Evans, H., Falzon, C., Frost, R., Ginley, S., Hockley, N., Hourahane, S., Jones, B., Jones, L., Korn, J, Ogden, P., Pagella, S., Pagella, T., Pawson, B., Reynolds, B., Robinson, D., Sanderson, B., Sherry, J., Skates, J., Small, E., Spence, B. and Thomas, C. (2011). *Chapter 20: Status and Changes in the UK's Ecosystems and their Services to Society: Wales*. UK National Ecosystem Assessment: Technical Report.

SI (1989). *The Sludge (Use in Agriculture) Regulations 1989*. Statutory Instrument 1989 No. 1263

SI (2016). *The Environmental Permitting (England and Wales) Regulations 2016*. Statutory Instrument 2016 No. 1154

Smith, K.A. and Williams, A.G. (2016). Production and management of cattle manure in the UK and implications for land application practice. *Soil Use and Management*, 32, 73-82

SRUC (2019). *Agricultural use of biosolids, composts, anaerobic digestates and other industrial organic fertilisers.* Technical Note TN699.

Webb, J. and Misselbrook, T. (2004). A mass flow model of ammonia emissions from UK livestock production. *Atmospheric Environment*, 38, 2163-2176.

Welsh Assembly Government (2011). *The code of good agricultural practice for the protection of water, soil and air for Wales*. Welsh Assembly Government, Defra, Environment Agency Wales, Countryside Council for Wales.

Welsh Government (2015) Glastir. The new sustainable land management scheme for Wales. Glastir Entry Booklet 2: Technical Guidance 2015.

Welsh Government (2017). *The Environmental Impact Assessment (Agriculture) (Wales) Regulations 2017 General Guidance*.

Welsh Government (2018). *Welsh Agricultural Statistics 2016*. National Statistics Publication.

Welsh Government (2019) Glastir. The new sustainable land management scheme for Wales. Glastir Advanced 2019. Rules Booklet 2: Whole farm code and management options.

Welsh Government. (2021). *Survey of agriculture and horticulture, June 2021*. Statistics for Wales.

Welsh Government (2022). *Farm incomes in Wales, 2020-21*. Statistical First Release. Statistics for Wales.

WRAP (2014). *A survey of the UK Anaerobic digestion industry in 2013. A report on the structure of the UK Anaerobic Digestion sector and the markets for its outputs*. WRAP

WRAP (2017). *Organics recycling industry status report 2015. A report on the status of composting and Anaerobic Digestion (AD) sectors in UK (England, Wales, Scotland and Northern Ireland).* WRAP.

WRAP (2016). Digestate and compost use in agriculture. Good practice guidance. WRAP.

WRAP Cymru (2016). *Survey of green waste compost production capacity in Wales*. WRAP.

WSI (2021). *The Water Resources (Control of Agricultural Pollution) (Wales) Regulations 2021*. Welsh Statutory Instrument 2021 No. 77 (W. 20).

11 Appendix 1

Table 11. Datasets used in the work package 2 report to establish the available landbank for organic materials

Organic material	Dataset	Notes	Source
Livestock manures	Survey of Agriculture and horticulture June 2021	Livestock numbers	Welsh Government
	COAPR 2021	Manure production (grazing and non-grazing livestock)	Welsh Statutory Instrument 2021 No 77 (W.20)
Digestate	NNFCC AD deployment database 2021	Location, feedstock quantity and type	NNFCC database (2021)
	Biofertiliser certification scheme website 2021	Current PAS 110 sites	Certified producers
	Compost/Biofertiliser Certification scheme annual report 2020	Production and digestate type Market destination	Compost/Biofertiliser Certification Schemes. Annual Report 2020
	Renewable Energy Assurance Limited (REAL)	Data on digestate production and market destination for certified plants in Wales	REAL
Compost	Compost sites 2015	Feedstock, certification and compost produced	WRAP Cymru (2015). Survey of green waste compost production capacity in Wales
	Compost certification scheme website 2021	Current PAS 100	Certified producers
	Compost/Biofertiliser Certification scheme annual report 2020	Production and compost type Market destination	Compost/Biofertiliser Certification Schemes. Annual Report 2020
	REAL dataset	Data on compost production and market destination for certified plants in Wales	REAL
Biosolids	ADAS dataset	Sewage treatment centre	ADAS data

		Production	
	NRW sludge returns DCWW 2020	Quantity to land Agricultural land used N (% dry solids)	DCWW/NRW
Permitted waste	NRW waste deployment and permit data 2020	Location Waste type Total permit (tonnes)	Dataset supplied by NRW.
	N content of selected waste types	Application rate	AHDB Nutrient management guide
Designation	**Dataset**	**Notes**	**Source**
Topography	Ordnance Survey	Slope gradient	
Watercourses, springs and boreholes	British Geological Survey CEH Rivers dataset	Includes rivers, canals, man-made channels etc.	CEH Digital River Network of Great Britain
Source Protection Zone	Location of SPZs	Spatial dataset	DataMapWales Source Protection Zones merged
Soil	Representative Soil Sampling Scheme 1969-2003	pH	Landis https://naturalresourceswales.sharefile.eu/d-s55ed72683ece4d769ac07bfaf10a5c33
	National soil Inventory 1983 and 1995	pH and metal concentration	Landis
SPA	Special protection areas boundaries	Spatial dataset	DataMapWales. Special Protection Areas
SAC	Special areas of conservation boundaries	Spatial dataset	DataMapWales. Special Areas of Conservation
Ramsar	Ramsar wetlands of international importance boundaries	Spatial dataset	DataMapWales. Ramsar wetlands of international importance
SSSI	SSSI boundaries	Spatial dataset	DataMapWales. Sites of Special Scientific Interest

NNR	National Nature Reserve boundaries	Spatial dataset	DataMapWales. National Nature Reserves
LNR	Local Nature Reserve boundaries	Spatial dataset	DataMapWales. Local Nature Reserves
Scheduled monuments	Archaeological sites of national importance	Spatial dataset	DataMapWales. Scheduled Monuments
Organic agriculture	ADAS dataset (in ALOWANCE)	See below: Glastir organic	
Glastir options (2020)	Glastir land extent under contract		Dataset supplied by Welsh Government