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Central Bedfordshire Development Strategy

Ecosystem Services Appendices

Publication January 2013

Security classification:
Protected

Spatial Evidence Base to improve Regulating Ecosystem Services in Central Bedfordshire APPENDICES

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Acknowledgements

This work was completed by the above authors, within the Group Project component of the MSc courses at Cranfield University, for Central Bedfordshire Council between February and 23 April 2012. The group would like to thank Laura Kitson at Central Bedfordshire Council, for the invaluable guidance, information and cooperation. We also thank our Course Tutor, Paul Burgess, for offering direction, and reading through several pages of report drafts. We also thank Caroline Keay, Ian Holman, Ian Truckell, Jacqueline Hannan, Timothy Farewell, Tim Hess, Rob Simmons, Pat Bellamy, and Humberto Perotto-Baldivieso, together with Mr Catlin of Church Farm and Claire Wardell of CBC.

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Appendix A: Introduction and Methodology

A1: Water Framework Directive and Groundwater Directive

Water Framework Directive: Status of Surface Water Bodies

Water quality in surface water bodies is classified according to the Water Framework Directive (WFDF) (2000/60/EC); legislation from the European Commission driving national governments to achieve 'good chemical status' and 'good ecological status' by 2015.

Chemical Status (Pesticides)

To achieve 'good chemical status' surface water bodies must comply with environmental standards for chemicals that are priority substances and/or priority hazardous substances listed in the Environmental Quality Standards Directive (2008/105/EC); the 33 priority substances can be found at the European Commission website (EC 2012) and include certain pesticides (biocides and plant protection products). Chemicals are classified as either 'good' or 'fail' for chemical status; the worst classified chemical drives the overall result.

Ecological Status (Nitrates, phosphates and pesticides)

Ecological status is defined in the WFD (2000/60/EC) (Article 2, sub-section 21) as 'an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters' (classification is provided in WFD (2000/60/EC), Annex V). 'Good ecological status' is based on three assessments of surface water bodies including: biological, physico-chemical (including phosphate as a quality element) and specific pollutants (hydromorphological aspects are also considered to assess 'high' status). Nutrients (nitrates and phosphates) and pesticides (biocides and plant protection products) are incorporated within the physico-chemical quality elements (Table A1) within specific pollutants (Figure A2) listed in Annex VIII of the WFD:

Table A1 Physico-chemical quality elements within ecological status classification (EA, 2011)

Quality element	Rivers	Lakes
pH	✓	✓[3]
Ammonia (total as N)	✓	✓
Phosphate	✓[1]	✓[2]
Dissolved inorganic nitrogen		
Dissolved oxygen	✓	✓
Specific pollutants (Annex VIII)	✓	✓
Acid neutralising capacity		✓

[1] Reactive phosphorus (unfiltered orthophosphate)
[2] Total phosphorus
[3] In lakes Acid Neutralising Capacity is assessed

Quality elements are assessed in terms of status (high, good, moderate, poor or bad) with the poorest element driving the overall result. For ‘good ecological status’ to be achieved all physico-chemical quality elements (including specific pollutants and phosphates) must be classified as ‘good status’ describing water quality which has the potential to support a functioning ecosystem, along with the biological classification which must also show ‘good status’, (EA 2011).

<u>WFD Specific Pollutants</u>

1. Organohalogen compounds and substances which may form such compounds in the aquatic environment.
2. Organophosphorous compounds.
3. Organotin compounds.
4. Substances and preparations, or the breakdown products of such, which have been proved to possess carcinogenic or mutagenic properties or properties which may affect steroidogenic, thyroid, reproduction or other endocrine-related functions in or via the aquatic environment.
5. Persistent hydrocarbons and persistent and bioaccumulable organic toxic substances.
6. Cyanides.
7. Metals and their compounds.
8. Arsenic and its compounds.
9. Biocides and plant protection products.
10. Materials in suspension.
11. Substances which contribute to eutrophication (in particular, nitrates and phosphates).
12. Substances which have an unfavourable influence on the oxygen balance (and can be measured using parameters such as BOD, COD, etc.).

Figure A2 Specific pollutants according to the WFD (2000/60/EC), Annex VIII)

Water Framework Directive and Groundwater (Daughter) Directive: Status of Groundwater Bodies

Water quality in groundwater is classified according to the Water Framework Directive (WFDF) (2000/60/EC) and the Groundwater (Daughter) Directive (2006/118/EC); legislation from the European Commission driving national governments to achieve ‘good chemical status’ and ‘good quantitative status’ by 2015. There are five chemical and four quantitative tests each assessed and given an independent status classification; results are compiled to give an overall chemical and quantitative status driven by the worst classification in each case. The worst result from the overall chemical and quantitative status is the overall groundwater status. (EA, undated-b)

Chemical status (Nitrates and pesticides)

Chemical status of groundwater is determined by five tests: Saline or other intrusion test, impact of groundwater on surface water test, groundwater dependent ecosystems chemical test, drinking water protected area test and general chemical assessment (GCA) test. The GCA tests concentrations of nitrate, pesticides and other chemicals in groundwater; these pollutant concentrations therefore contribute to driving the chemical status (EA undated-b). The Groundwater Directive (2006/118/EC) outlines standards for nitrates and pesticides (Table A2) for assessing groundwater chemical status.

Table A2 Standards for nitrates and pesticides for assessing groundwater chemical status as defined by the Groundwater Directive (2006/118/EC)

Pollutant	Quality standards
Nitrates	50 mg/l
Active substances in pesticides, including their relevant metabolites, degradation and reaction products (1)	0,1 μg/l 0,5 μg/l (total) (2)

(1) 'Pesticides' means plant protection products and biocidal products as defined in Article 2 of Directive 91/414/EEC and in Article 2 of Directive 98/8/EC, respectively.
(2) 'Total' means the sum of all individual pesticides detected and quantified in the monitoring procedure, including their relevant metabolites, degradation and reaction products.

A2: Nitrate Vulnerability Zones

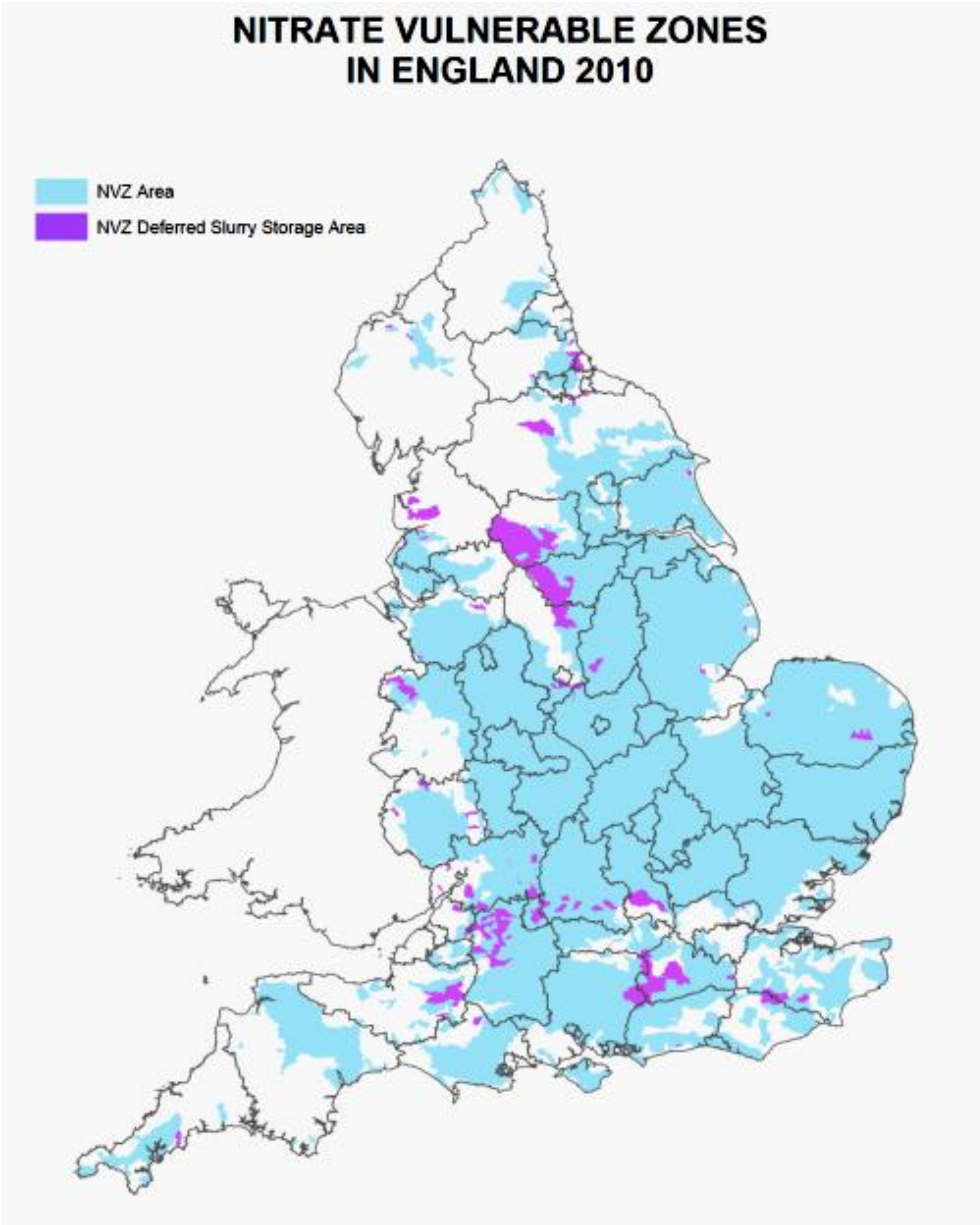

Figure A3 Nitrate Vulnerability Zones in England (Defra updated 2010)

A3: Summary description of LandIS data used

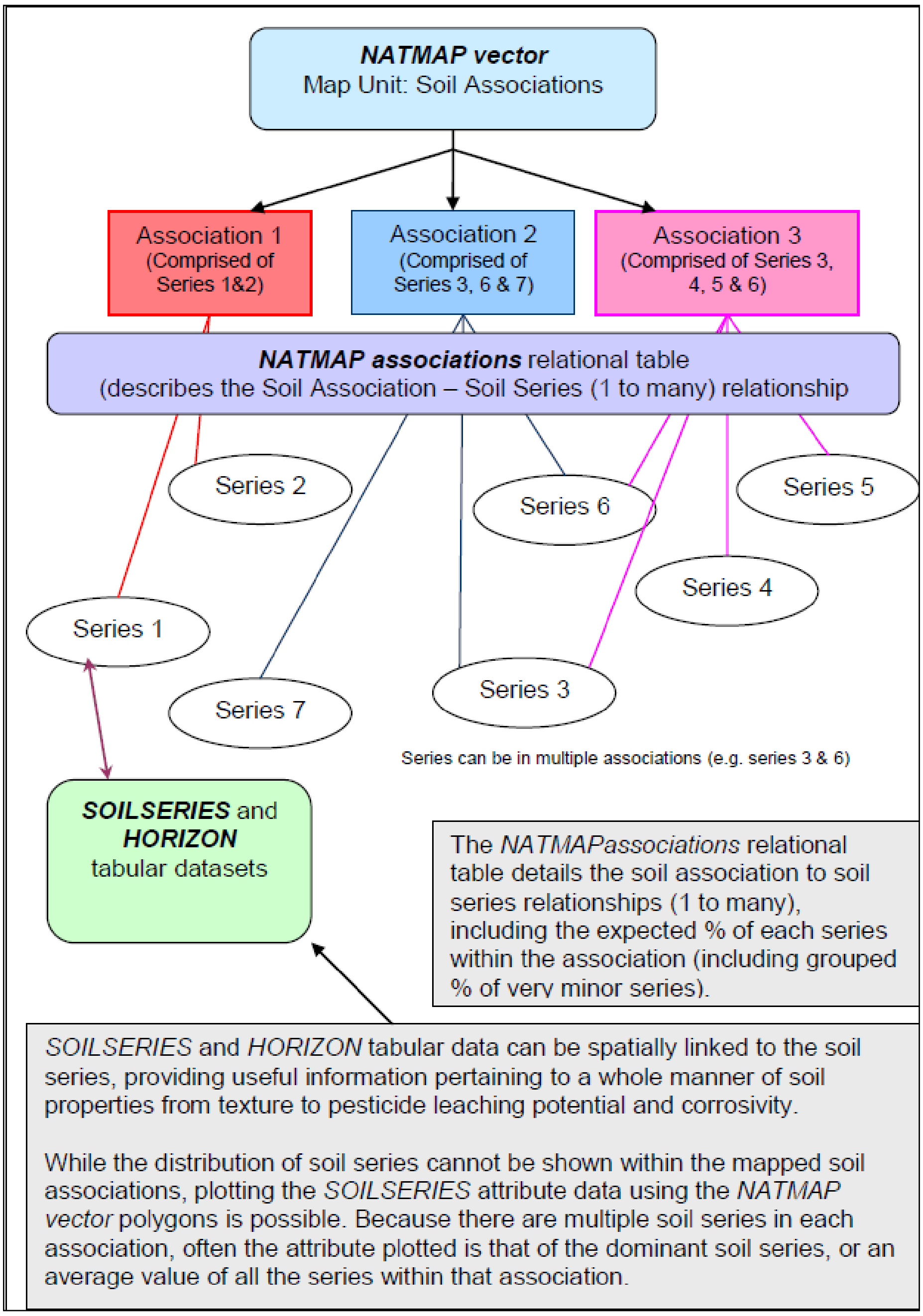

Figure A4 Summary Description of LandIS data (Farewell 2012)

A4: SQL Codes for Extraction of SOC data

SQL Codes developed by Caroline Keay (pers. comm.) to extract the SOC data required from LandIS datasets by MUSID code. The result was an excel datasheet with mean, minimum and maximum soil organic carbon percentage at different depths (0-30, 30-100, and 100-150 cm) for each value of MUSID. This was carried out for arable land and permanent grassland, which are the first and second SQL codes, respectively. This data was then converted from percentage weight to tons of carbon per hectare using bulk density data, and conversion factors were used to find SOC density values for woodland and urban land uses.

Arable SQL Code

```
"select b.musid, round(sum((a.oc*b.series_pc)/c.totpc),2) Av_carbon, min(a.oc) MIN_CARBON, max(a.oc) MAX_CARBON, MIN(a.LOWER_DEPTH) MIN_DEPTH, MAX(a.LOWER_DEPTH) MAX_DEPTH

from landis.horizon_fundamentals_ar a, landis.natmap_v3_associations b, ss01cak.musid_totpc c

where a.series=b.series and b.musid=c.musid and a.upper_depth=0

group by b.musid

order by b.musid"
```

Permanent Grassland SQL Code

```
"select b.musid, round(sum((a.oc*b.series_pc)/c.totpc),2) Av_carbon, min(a.oc) MIN_CARBON, max(a.oc) MAX_CARBON, MIN(a.LOWER_DEPTH) MIN_DEPTH, MAX(a.LOWER_DEPTH) MAX_DEPTH

from landis.horizon_fundamentals_pg a, landis.natmap_v3_associations b, ss01cak.musid_totpc c

where a.series=b.series and b.musid=c.musid and a.upper_depth=0

group by b.musid

order by b.musid"
```

A5: BAP Scenario Maps

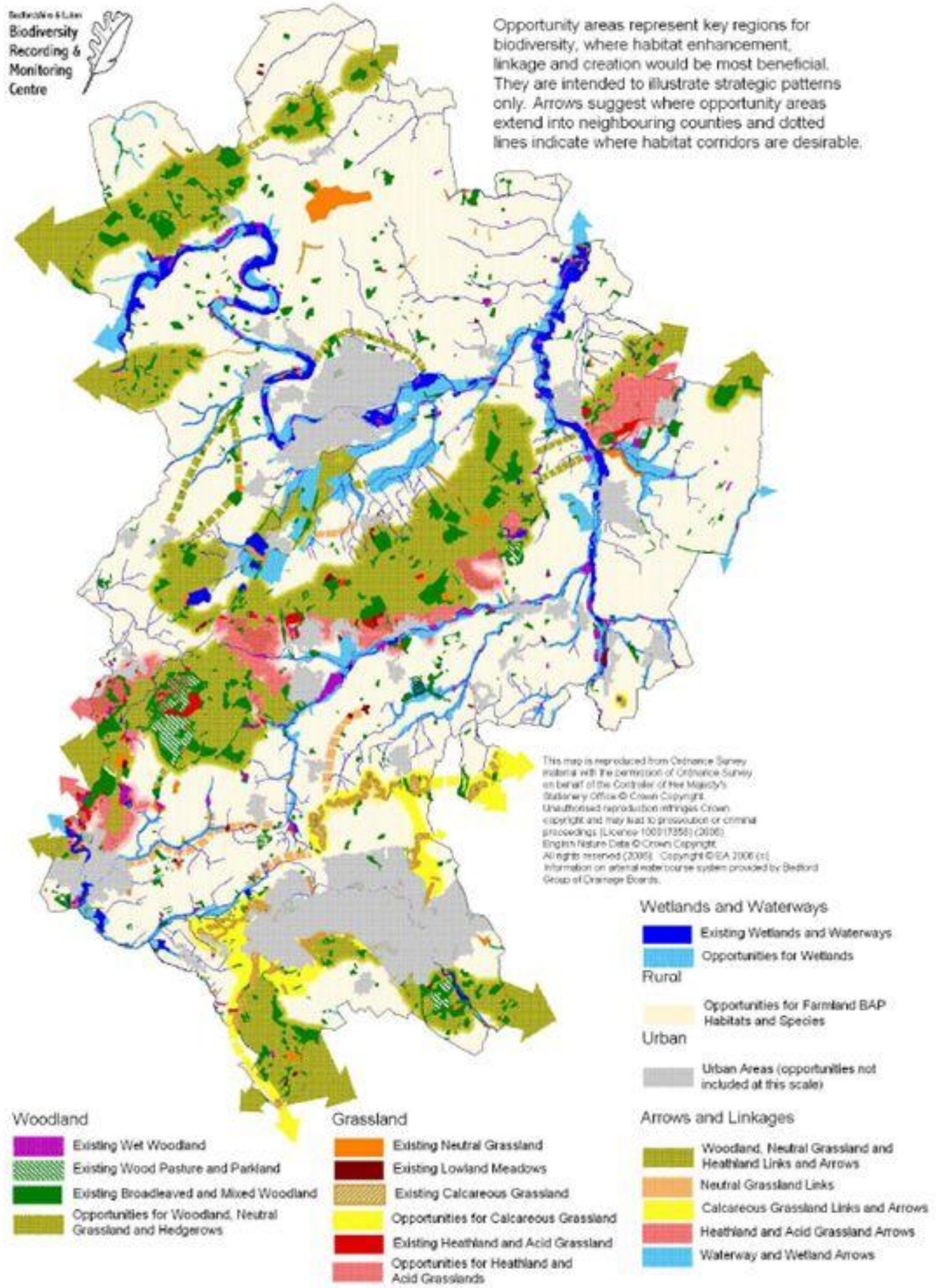

Figure A5 Opportunity areas for the habitat enhancement, linkage and creation as part of the BAP in Luton and Bedfordshire.

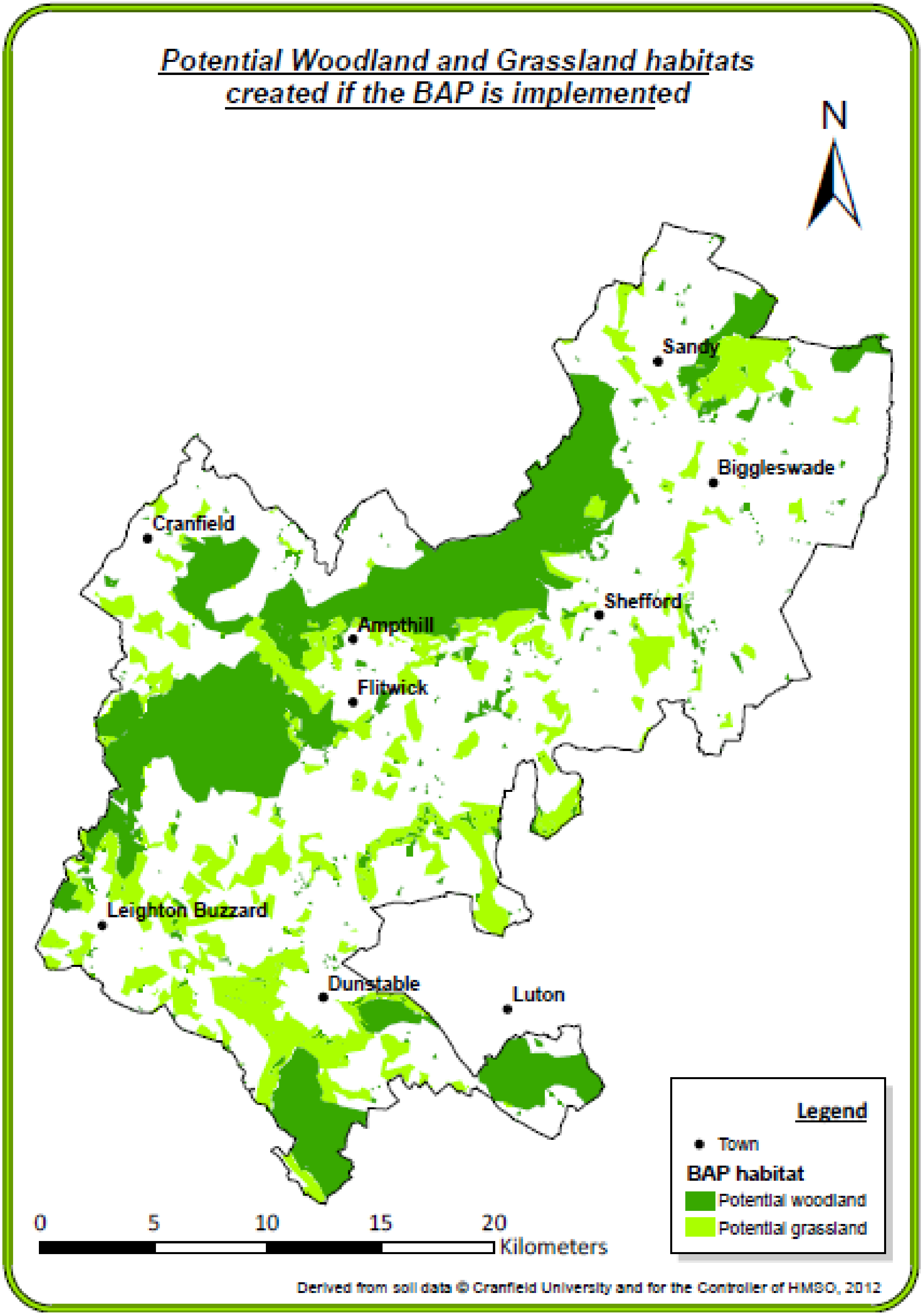

Figure A6 Map generated to use in BAP scenarios: it was assumed all areas where there was opportunity for woodland or grassland in figure 1.8 would become woodland or grassland in the future, for the purposes of comparison in the scenario.

A6: Curve Number Method

The SCS Curve Number (CN) method was empirically developed in the USA. It is used to predict the runoff volumes caused by individual storms. It is applicable to catchments smaller than 6500 ha, with a maximum time of concentration of 0.1 – 10 hours (NRCS 2002). The model relates the runoff with the catchment features, the amount of rainfall and the antecedent wetness of the soil (USDA 2012). Catchment characteristics are represented by the Curve Number, which ranges from 0 (maximum of water storage in soil) to 100 (minimum of water storage in the soil). CN used in this project are presented in table 2 and 3. The main equation of the model is:

$$q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Where:
q = direct runoff depth[2] (mm).
P = storm rainfall (mm).
0.2S = I_a = Initial abstraction (mm). It is the water that is infiltrated before runoff occurs.
S = The potential maximum soil moisture retention after runoff begins (mm). S is defined as:

$$S = \frac{25400}{CN} - 254$$

As the CN, S vary according to the soil wetness. Thus, three antecedent runoff conditions were defined (table A3). In other words, the greater the previous soil moisture, the smaller the initial abstraction (I_a). CN's are specified for such three conditions.

Table A3 Quantitative definition of the antecedent runoff conditions (USDA 2012).

Antecedent runoff conditions	Total rainfall in the 5 previous days (mm)	
	Period without vegetative growth	**Period with vegetative growth**
I.Dry	Less than 12.7	Less than 35.6
II.Average	12.7 – 27.9	35.6 – 53.3
III.Wet	More than 27.9	More than 53.3

Four catchments Characteristics were taken into account to define the CN (Hess 2010, USDA 2012):

- Land use: The Chapter 9 of the National Engineering Handbook (NEH) contains tables in which a wide range of land uses are considered in the determination of the CN.
- Soil conservation practice: There are several CN values for each land use according to the soil treatment (e.g. contouring, terracing).
- Hydrologic Soil Groups (HSGs): Soils are grouped in four categories (table A7) according to their minimum rate of infiltration after prolonged wetting (infiltration rates are measured for bare soil). The HSG also takes into account the transmission (movement of water within the soil) rate, which is controlled by the soil profile:

    - **Group A:** The soil has an elevated rate of water transmission (greater than 7.6 mm/hr). In addition, the water infiltration rate is high even in thoroughly wetted soils. The soils consist mainly in well drained sand and gravel.
    - **Group B:** These soils have a smaller water transmission rate (3.8 – 7.6 mm/hr). The infiltration rate is moderate when the soil is thoroughly wetted. These soils usually present loamy sand or sandy loam texture.

- **Group C:** The water transmission rate of this group of soil is low (1.3 – 3.8 mm/hr). The infiltration rate is also low when the soil is thoroughly wetted. These soils have moderate fine to fine texture. They commonly have a moderately impermeable layer which difficult downward movement of water.
- **Group D:** The water transmission rate is very low (0 – 1.3 mm/hr). The infiltration rate is also very low, thus this soils have a high runoff potential. Within this group we find clay soils, soils with a clay pan or a clay layer close to the surface, soils with a permanent high water table, and shallow soils over impermeable material.

- <u>Soil hydrologic condition:</u> The impacts of land management are reflecting in this soil property. Five field-soil conditions were used, from Excellent to Very Poor. For a certain land use and HSG, the highest and the lowest CN from Hess et al (2010) were used for Poor and Excellent (or Good for woodland) respectively. Very poor conditions are referred to a soil degraded to the point that it behaves as a soil within a SHG of higher runoff potential. For instance, a soil with Very Poor condition would have a CN corresponding to a HSG B, rather than HSG A (Environment Agency, undated). Linear interpolation between the values given in the NEH tables were made to derive a CN for the different soil hydrologic conditions. For agricultural soils:

  - **Excellent:** Good soil structure and presence of practices to reduce runoff transmission from the field.
  - **Good:** Good soil structure but only few practices to reduce runoff transmission from the field.
  - **Fair:** Either some degradation signs in the soil structure or good soil structure but some management activities that increase runoff.
  - **Poor:** Poor soil structure and management activities that increase runoff.
  - **Very Poor:** Important soil structure degradation and lack of practices to reduce runoff transmission.

  For semi-natural soils, the hydrologic soils conditions refer to the grazing pressure over the soil and the vegetation. Therefore, a Excellent condition have both a good soil structure and vegetation cover, while a Very Poor soil present compaction and vegetation overgrazing.

  For woodland, there are only four soil hydrologic conditions (Good to Very Poor). For commercial forests, the assessment of the soil hydrologic condition is mainly based on the forest stage of growth. In orchards, the soil hydrologic condition is determined by the vegetation management between tress.

Urban and residential land

Many factors such as the amount of impervious areas and their connectivity with the drainage system or other pervious areas are important in order to estimate the runoff generation in urban areas. CN for different types of urban covers are found in the NEH. Some assumptions are made in such table:

- Each cover type has an assumed percentage of pervious area.
- The pervious urban areas are considered as pasture in good hydrologic condition.
- A CN of 98 is assigned to impervious areas.
- Impervious areas are directly connected to the drainage system.
- The soil hydrologic condition is only taken into account in open spaces. It has three categories, Good, Fair, and Poor (USDA 2012).

Table A4 CNs used to estimate the runoff in the CBC. CN = 0 (maximum water storage in soil), CN = 100 (minimum water storage in soil). Adapted from Hess et al (2010) and USDA (2012).

Soil	Soil Condition	Pasture	Arable land	Semi-natural vegetation	Woodland
A	Very Poor	78	67	78	45
	Poor	68	66	68	40
	Fair	58	64	58	35
	Good	49	63	49	30
	Excellent	39	62	39	
B	Very Poor	86	82	86	66
	Poor	79	77	79	54
	Fair	66	72	66	42
	Good	52	67	52	30
	Excellent	39	62	39	
C	Very Poor	89	86	89	77
	Poor	86	85	86	75
	Fair	82	83	82	72
	Good	78	82	78	70
	Excellent	74	81	74	
D	Very Poor	89	88	89	83
	Poor	89	88	89	81
	Fair	86	87	86	79
	Good	83	86	83	77
	Excellent	80	85	80	

Table A5 CNs for the urban land cover types found in CBC. CN = 0 (maximum water storage in soil), CN = 100 (minimum water storage in soil) (USDA 2012).

Soil type	Soil condition	Residential districts (65% impervious area)	Commercial and Business (85 % impervious)	Impervious area (dirt)	Open spaces
A	Poor	77	89	72	68
	Fair				49
	Good				39
B	Poor	85	92	82	79
	Fair				69
	Good				61
C	Poor	90	94	87	86
	Fair				79
	Good				74
D	Poor	92	95	89	89
	Fair				84
	Good				80

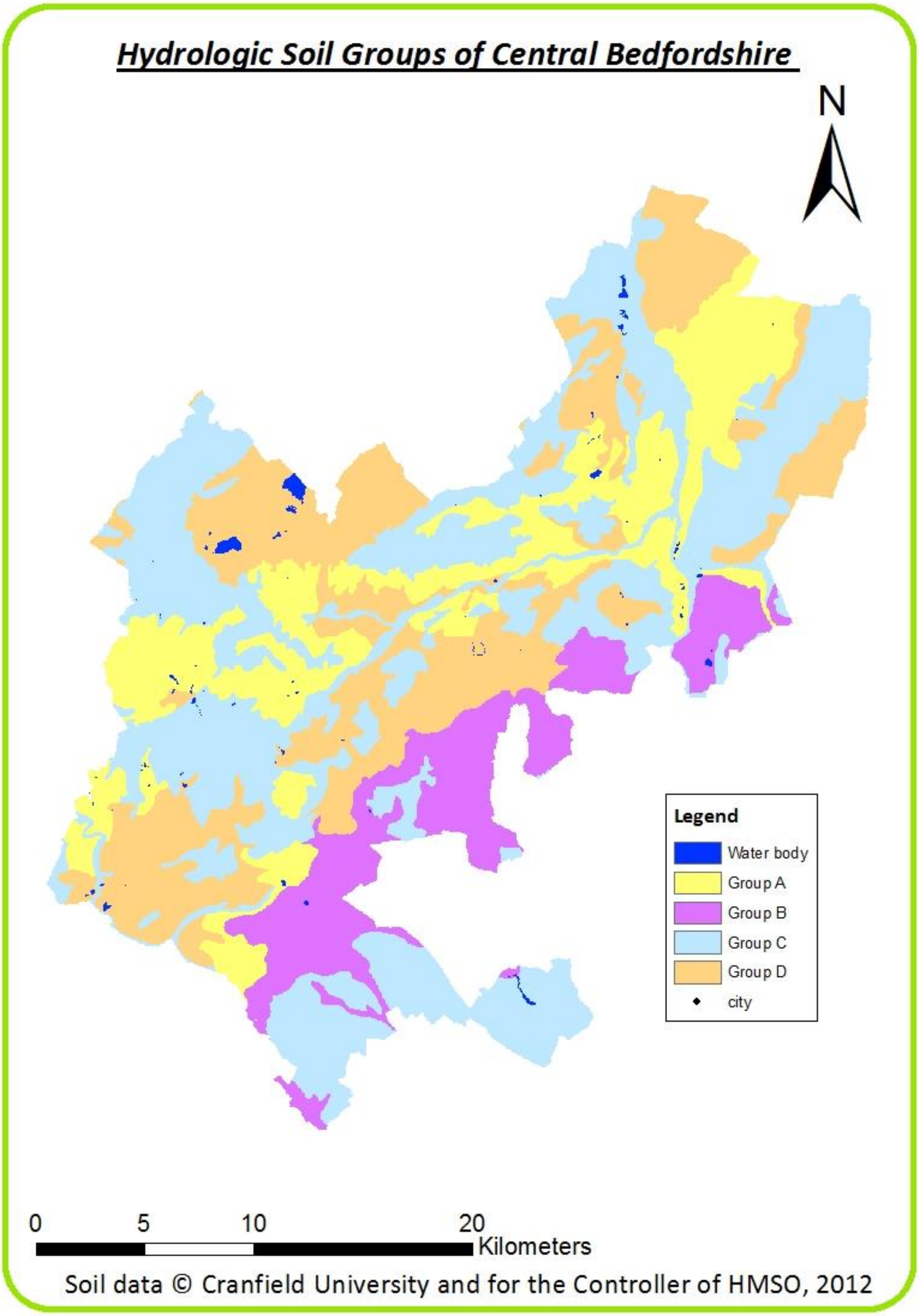

Figure A7 Hydrologic Soil Groups (HSG's) in Central Bedfordshire. The map was made using the equivalence table between the HOST classification and the HSG's made by Cranfield University (J. Hollis, unpublished data).

Table A6 The equivalence between the four hydrologic soil groups (HSGs) used in the CN method and the soil classification used to display the results in every ecosystem services, excepting the runoff. It was made by comparison of the map shown in Figure A7 and the soil map of the LandIS dataset (Figure 2.6 in main report). The same soil type can sometimes be found in more than one HSG. The word "High" is used to indicate the most representative HSG and the word "Low" indicates a low proportion of coincidence between a certain soil type and a given HSG.

Soil Type	Soil A	Soil B	Soil C	Soil D
Deep clay			Low	**High**
Deep loam	Low		**High**	
Deep loam over gravel	**High**		Low	
Deep loam to clay			**High**	
Deep sandy	**High**			
Deep silty to clay		**High**		
Loam over chalk		**High**		
Loam over red sandstone	**High**			
Seasonally wet deep clay			**High**	Low
Seasonally wet deep peat to loam	**High**			
Shallow silty over chalk		**High**		
Silty over chalk		**High**		

A7: USLE Implementation

Three factors (LS, C, and K) of the USLE were calculated at a finest scale as allowed by the available data. Two other (R and P) were assumed to be constant over all the study area. The following describes the calculation of these factors accordingly to the framework of the Revised USLE Handbook (Renard et al 1997).

K factor

Definition

K can be calculated as a function of four variables:

$$K= [2.1*10^{-4}*(12\text{-}OM)*M^{1.14} + 3.25*(s-2) + 2.5*(p-3)]/100$$

(Wischmeier and Smith 1978)

And further K_m =1.313*K, where indicates that K is expressed in metric units (Renard et al 1997).

K_m is in $t.hr.MJ^{-1}.mm^{-1}$.

OM is the fraction of organic matter in the topsoil (weight basis).

S is an index of the soil structure class (table A7).

P is an index of the permeability of the soil (table A8).

M is defined by M = (% silt + % fine sand)*(% silt+% total sand). The particle diameter ranges are defined in table A8.

Algorithm

The data originally available was the properties of soil for each horizon, each soil series, and each land use. Only the information relative to the topsoil was extracted from the original data for OM, S and texture. For permeability, the total saturated conductivity was calculated across the whole profile. Relevant soil properties corresponding to the actual land use at a location were extracted by intersection of the soil map (NSRI 2009a) with the Corine land cover map (EIONET 2006); different properties were used for “arable land”, “grassland” and “other” categories. The extracted information was then converted into the form required for USLE inputs in ArcGIS. Then, a weighted average of the inputs within each *Map Unit*[1] was done in Microsoft Excel. Lastly, the results were averaged at the appropriate scales to help illustration. The detailed flow-chart of data treatment for K calculation is shown on Figure A8.

[1] By *Map Unit* is meant the land unit used by NSRI in the National Soil Map (NSRI 2008c)

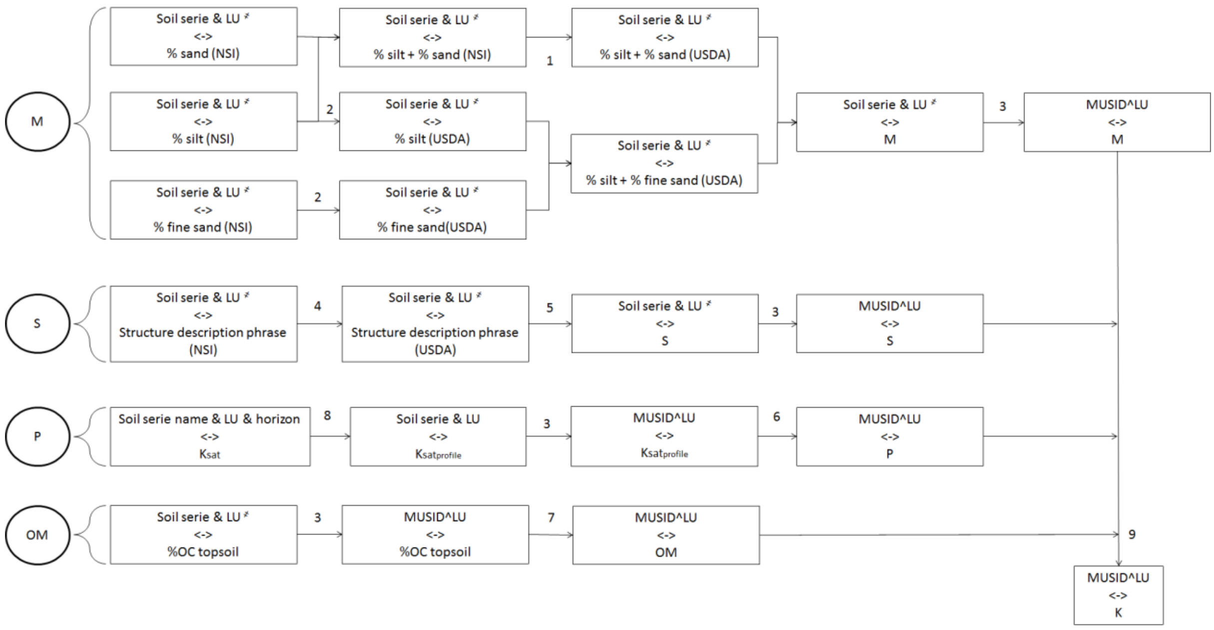

Figure A8 Flow-chart of the algorithm of the K calculation*

*MUSID^LU refers to individuals polygons resulting from the intersection of The National Soil Map and the Corine Dataset. The symbol <-> represent a unique association between data.

⸸ : topsoil data

1- NSI and USDA both define the minimum diameter of silt particles as 0.002mm and the maximum diameter of sand particles as 2mm, therefore $[\%silt+\%sand]_{(NSI)}=[\%silt+\%sand]_{(USDA)}$ without further calculation (table 3).
2- It was assumed here a homogeneous particle size distribution and converted the NSI % silt and %fine sand into USDA % silt and %fine by multiplying by a factor of $\alpha=\frac{0.05-0.002}{0.06-0.002}$ for %silt and $\beta=\frac{0.1-0.05}{0.2-0.05}$ for % fine sand (table 3).
3- A weighted average was used for each *Map Unit* taking into account the relative abundance of the different series within each map unit.
4- A straight forward reclassification was done grouping fine description of soil structure given by the NSI into broader categories used by the USDA (table 1).
5- A reclassification was done using of table 1.
6- A reclassification was done using of table 2.
7- A factor of 1.72 was applied to convert organic carbon into organic matter weight fraction (Brady and Weil 2002).
8- The total conductivity was classically obtained by $[1/Ksat_{profile}]=sum[1/Ksat_{horizon\ i}]$, i=1..n; n being the number of horizons across the profile.
9- Raster calculator was used with K algebraic approximation by Wischmeier and Smith (1978).

Table A7 Soil structure index used in the USLE (USDA 1997)

S	Descriptive class
1	Very fine granular
2	Fine granular
3	Medium to coarse granular
4	Blocky, platy or massive

Table A8 Soil permeability classes used in the USLE (*Soil Survey Division Staff 1993)*

P	Descriptive phrase	K_{sat} range ($cm.day^{-1}$)
1	Very High	$864 < K_{sat}$
2	High	$86.4 < K_{sat} < 864$
3	Moderately High	$8.64 < K_{sat} < 86.4$
4	Moderately Low	$0.864 < K_{sat} < 8.64$
5	Low	$0.0864 < K_{sat} < 0.864$
6	Very Low	$K_{sat} < 0.00864$

Table A9 Particles diameter ranges given by the NSI and used by the USDA (*Soil Survey Division Staff 1993* and NSRI 2009a)

Particle name	Diameter range (USDA) [mm]	Diameter range (NSI) [mm]
Silt	0.002 – 0.05	0.002 – 0.06
Fine sand	0.05 – 0.1	0.06 – 0.02
Total sand	0.05 - 2	0.02 – 0.2

LS factor

Definition

The slope factor depends on the slope length and slope steepness.

Slope length is defined as the distance between the point where overland flow is originated and the point where either sedimentation occurs or the run-off water joins into a well-defined channel (García-Rodriguez and Giménez-Suárez 2010).

Algorithm

The only data required for slope length and slope steepness is a digital terrain model (DTM). A 10m resolution Ordnance Survey Land-Form DTM (Ordnance Survey 2012) was used as input data. Then it was run a C++ program made by Van Remortel et al. (2004) that calculates L and further LS factor accordingly to the flow-chart on figure 2. In addition to the DTM, the program asks for some parameter: two cut-off slope angles. The default setting of 0.5 (and 0.7) for slopes greater (respectively less) than 5% were kept. In this way sedimentation occurs when slope variation reaches such a threshold. If the threshold is not reached, the cumulative slope length is simply the length of the flow-path taken by water from the considered point to the bottom of the basin.

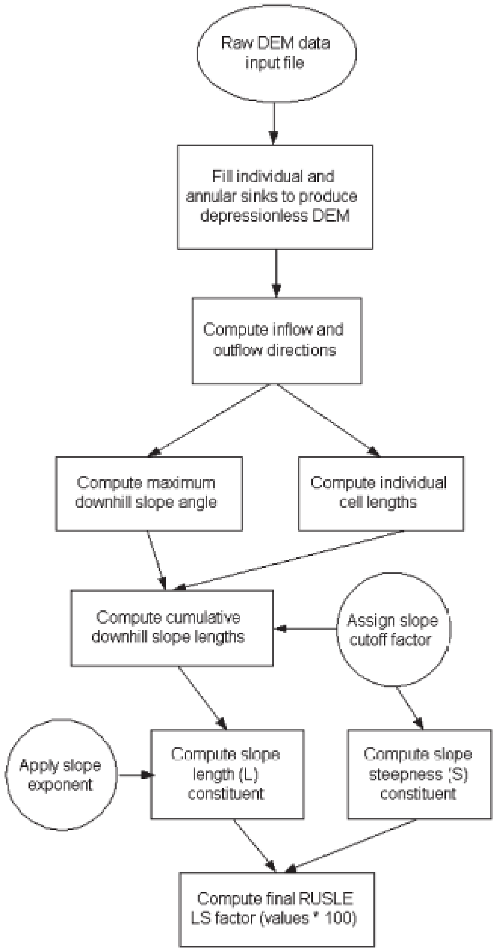

Figure A9 Steps of the calculation of LS factor by the C++program by Van Remortel et al. (2004) - figure from the author

L is then calculated by the program as:

$$L = (\lambda/22.13)^m$$

Where λ is the cumulative slope length in meters as calculated above, and m is a function of the local slope angle.

The slope angle is directly derived from the DTM. Finally, the program calculates S according to the RUSLE handbook:

$$S = 10.8 * \sin(\theta + 0.03) \qquad \text{if } \theta < 9\% \text{ and}$$

$$S = 16.8 * \sin(\theta - 0.05) \qquad \text{if } \theta >= 9\%.$$

LS is then calculated as L*S.

Further information about the program can be found in Van Remortel et al. (2001) and Van Remortel et al. (2004).

C factor

The cropping factor requires data about land cover. Corine land cover map 2006 was used as the baseline. The value of the C factor for non-urban land covers was inferred from tables (Morgan 2005, Stone and Hilborn 2000). However, the land cover class called Arable Land in Corine 2006 includes many different types of crops (EIONET 2006). The C values of every different types of crop included within this land cover type were weighted according to their abundance in the Luton & Bedfordshire county (Defra 2009). As a result, the C value used for the arable land category was representative of the variety and abundance of different crops in the area.

Urban areas consist of concrete and non-concrete areas. As consequence, the C factor in urban areas was estimated weighting the C factor for concrete areas and the C factor for the estimate percentage of non-concrete areas. The C factor for concrete was assimilated to the minimum C factor found for non-urban areas, i.e. to forest, because erosion in concrete areas may be mainly reduced to dust particles. The behaviour of non-concrete areas was assumed similar to that of grass. The proportion of non-concrete areas were estimated according with the percentage of pervious areas for the different urban land cover types indicated in the National Engineering Handbook (USDA, 2012), in order to be coherent with the assumptions made in the runoff calculations. The C factor for construction sites was estimated as the average of the C factor for their different life cycle stages (Kuenstler 1998). The C factor of dump sites was assimilate to the C factor for construction sites. Finally, mineral extraction sites were considered bare soil. C values are summarized in table A10.

Table A10 Land cover categories and the associated C values (Morgan 2005, Stone and Hilborn 2000, Defra 2009).

Description	C-value
Discontinuous urban fabric (residential areas -35% grass-)	0.009
Industrial or commercial units (15% grass)	0.005
Airports (75% grass)	0.019
Mineral extraction sites	1
Dump sites	0.65
Construction sites	0.65
Green urban areas (90 % grass)	0.023
Sport and Leisure facilities (90 % grass)	0.023
Arable land	0.35
Pasture	0.025
Semi-natural Woodland	0.001
Transitional woodlands and scrubs	0.015
Water	0

The effects of agri-environment schemes in the C value were not taken into account because there was no detailed information about the management practices applied within each field.

P factor

It was assumed that no management techniques to prevent erosion were carried out in any field of the area in order to set a potential erosion map of the worst situation. In addition, the current agri-environment schemes applied in the area were not considered because there were no detailed information of what specific management practices are carried out in each field. Therefore, the P factor was considered as 1. However, in one of the scenarios and one the case studies, the variations of this factor may be very useful to assess the efficiency of certain land management practices to prevent erosion.

R factor

Daily rainfall records since 1989 to 2006 were obtained from Silsoe campus of Cranfield University and analyzed in order to calculate this factor. However, rainfall data available for the area were not enough precise to estimate the R factor as explained in the Revised USLE handbook. Therefore, the rainfall erosivity was assessed using an alternative procedure, i.e. the Modified Fournier Index. Furthermore, the Modified Fournier Index has been proved as a good estimator of the rain aggressivity in UK (Gabriels 2006). Finally, some studies use the MFI as the value of the R factor in the USLE equation (e.g. Gallego-Alvarez et al 2002).

$$MFI = \sum(p^2/ P)$$

Where:

p = Monthly rainfall amount (mm).
P = Annual rainfall amount (mm).

A MFI was estimated for each individual year. The final MFI was calculated as an average of the value obtained for each year. The resulting R factor was 66.14 $MJ.mm.ha^{-1}.h^{-1}.y^{-1}$.

A8: Water Quality Methodology Details

1. Initial layers description and classification

1. *Potential Soil Erosion Risk*

Soil erosion risk layer (see section A6) has been reclassified into a 6 levels range by using Natural Breaks (Jenks) classification in ArcGIS. Units are t/ha/year

Table A11 Soil erosion risk reclassification

Range	Soil Erosion Risk
Very Low	0 – 19.24
Low	19.24 – 51.19
Moderate	51.19 – 87.19
High	87.19 – 138.81
Very High	138.81– 292.51
Extremely High	292.51 – 1201.29

2. *Phosphate overland flow risk*

Phosphate overland flow risk layer is a modification of soil erosion risk layer by deleting the risk from the attribute table for those landuses that do not have phosphate risk (table A19).

3. *Pesticide Potential Leaching Risk (Source: NSRI, 2009; NSRI, 2012)*

Table A12 Pesticide potential leaching risk definition and classification

Pesticide leaching risk (MAPUNITleaching_t)		Definition
Very Low		N/A
Low		**Soils of low leaching capacity through which pesticides are unlikely to leach, includes:** • Impermeable soils over soft substrates of low or negligible storage capacity that sometimes conceal groundwater bearing rocks at depth. • Upland peaty soils over a variety of subsrtates, some with deep groundwater.
Moderate	M1	**Soils of intermediate leaching capacity with a moderate ability to attenuate pesticide leaching, includes:** • Deep loamy soil over chalk with deep groundwater. • Deep loamy soil over fissured hard rock with deep groundwater. • Deep loamy soil over soft limestone with deep groundwater. • Deep loamy soil over soft sandstone with deep groundwater. • Deep loamy soil; groundwater at moderate depth. • Deep loamy soil; groundwater at shallow depth. • Deep loamy soils over hard non-porous rocks - no groundwater present. • Slowly permeable soils over soft limestone with deep groundwater. • Slowly permeable soils over soft sandstone with deep groundwater. • Slowly permeable soils with low storage capacity over soft substrates of low or negligible storage capacity that sometimes conceal groundwater bearing rocks at depth. • Slowly permeable soils with relatively high storage capacity over soft substrates of low or negligible
	M2	**Soils of intermediate leaching capacity with a moderate ability to attenuate pesticide leaching, includes:** • Drained peat and loamy soils with high organic matter; groundwater at shallow depth.
High	H1	**Soils of high leaching capacity with little ability to attenuate non-adsorbed pesticide leaching which leave underlying groundwater vulnerable to pesticide contamination, includes:** • Rapidly permeable soil; groundwater at very shallow depth (60cm). • Shallow gravelly soil; groundwater at moderate depth (750cm). • Shallow soil over chalk with deep groundwater (2000cm). • Shallow soil over fissured hard rock with deep groundwater (2000cm). • Shallow soil over soft limestone with deep groundwater (2000cm). • Shallow soils over hard non-porous rocks - no groundwater present.

		• Slowly permeable soil; groundwater at very shallow depth (60cm). • Undrained peat; groundwater at the surface.
	H2	**Soils of high leaching capacity with little ability to attenuate non-adsorbed pesticide leaching which leave underlying groundwater vulnerable to pesticide contamination, includes:** • Sandy soil with low organic matter over chalk with deep groundwater. • Sandy soil with low organic matter over soft sandstone with deep groundwater. • Sandy soil with low organic matter; groundwater at moderate depth. • Sandy soil with low organic matter; groundwater at shallow depth
	H3	**Soils of high leaching capacity with little ability to attenuate non-adsorbed pesticide leaching which leave underlying groundwater vulnerable to pesticide contamination, includes:** • Moderately shallow soil over chalk with deep groundwater. • Moderately shallow soil over fissured hard rock with deep groundwater. • Moderately shallow soil over gravel; groundwater at moderate depth. • Moderately shallow soil over gravel; groundwater at shallow depth. • Moderately shallow soil over soft limestone with deep groundwater. • Moderately shallow soils over hard non-porous rocks - no groundwater present. • Sandy soil with moderate organic matter over soft sandstone with deep groundwater. • Sandy soil with moderate organic matter; groundwater at moderate depth. • Sandy soil with moderate organic matter; groundwater at shallow depth
Very High		N/A
Excessively High		N/A

4. *Pesticide Potential Runoff Risk(Source: NSRI, 2009; NSRI, 2012)*

The pesticide runoff data (MAPUNITrunoff_t) from LandIS included both runoff potential of the soil and adsorption potential of the soil. When classifying this layer for our pesticide and phosphate runoff risk map we made two assumptions:

1) We assumed that soil with high potential to adsorb pesticides would also have high potential to adsorb phosphate.
2) We took the mid-point classification between runoff potential and adsorption potential for the overall risk classification, taking the worst case scenario for all classifications.

Table A13 Pesticide Potential Runoff Risk(Source: NSRI, 2009; NSRI, 2012)

Pesticide and phosphate runoff risk (MAPUNITrunoff_t)	Definition
Very Low	• Soils with very low run-off potential but very low adsorption potential.
Low	• Soils with low run-off potential but very low adsorption potential. • Soils with low run-off potential but low adsorption potential. • Soils with very low run-off potential but low adsorption potential. • Soils with very low run-off potential and moderate adsorption potential. • Soils with very low run-off potential and high adsorption potential.
Moderate	• Soils with high run-off potential and low adsorption potential. • Soils with moderate run-off potential and low adsorption potential. • Soils with moderate run-off potential and moderate adsorption potential. • Soils with low run-off potential and moderate adsorption potential. • Soils with low run-off potential and high adsorption potential. • Soils with moderate run-off potential but very low adsorption potential.
High	• Soils with very high run-off potential but moderate adsorption potential. • Soils with high run-off potential but moderate adsorption potential. • Soils with moderate run-off potential but high adsorption potential. • Soils with very high run-off potential but low adsorption potential. • Soils with very high run-off potential but very low adsorption potential.
Very High	• Undrained peat with very high run-off potential and groundwater at or near the surface. Not normally farmed and probably with a high adsorption potential. • Upland peaty soils with high or very high run-off potential. Not normally farmed and probably with a high adsorption potential.

5. *Nitrate Potential Leaching Risk (*Jones and Thomasson, 1990)

Table A14 Nitrate Potential Leaching Risk definition and classification

Nitrate Risk (MAPUNITnrisk_t)	Definition
Very Low	N/A
Low	Dense, slowly permeable loams and clays
Moderate	Deep permeable medium loams
High	Deep permeable light loams
Very High	N/A
Excessively High	Deep permeable sands; shallow soil over porous or well fissured rock

6. *Potential Risk of soil leaching to groundwater (Source: NSRI, 2009; NSRI, 2012)*

Table A15 Potential Risk of soil leaching to groundwater definition and classification

<table>
<tr><th colspan="2">Risk of soil leaching to groundwater (MAPUNITgwpp_t) Nb. gwpp means Groundwater Protection Policy</th><th>Definition</th></tr>
<tr><td colspan="2">Very Low</td><td>N/A</td></tr>
<tr><td colspan="2">Low</td><td>• Soils in which pollutants are unlikely to penetrate the soil layer either because water movement is largely horizontal or because they have a large ability to attenuate diffuse source pollutants.</td></tr>
<tr><td rowspan="2">Moderate</td><td>M1</td><td>• Soils of intermediate leaching potential which have a moderate ability to attenuate a wide range of diffuse source pollutants but in which it is possible that some non-adsorbed diffuse source pollutants and liquid discharges could penetrate the soil layer.</td></tr>
<tr><td>M2</td><td>• Soils of intermediate leaching potential which could possibly transmit some non-adsorbed pollutants and liquid discharges, but which are unlikely to transmit adsorbed pollutants because of their high adsorption potential.</td></tr>
<tr><td rowspan="3">High</td><td>H1</td><td>• Soils of high leaching potential, which readily transmit liquid discharges because they are either shallow, or susceptible to rapid bypass flow directly to rock, gravel or groundwater.</td></tr>
<tr><td>H2</td><td>• Deep, permeable coarse textured soils of high leaching potential, which readily transmit a wide range of pollutants because of their rapid drainage and low attenuation potential.</td></tr>
<tr><td>H3</td><td>• Coarse textured or moderately shallow soils of high leaching potential, which readily transmit non-adsorbed pollutants and liquid discharges but which have some ability to attenuate adsorbed pollutants because of their relatively large organic matter or clay content.</td></tr>
<tr><td colspan="2">Very High</td><td>N/A</td></tr>
<tr><td colspan="2">Excessively High</td><td>N/A</td></tr>
</table>

NOTE: As these layer is referred to general pollutants, for this model it has been take into account for possible phosphate leaching, despite it is known that leaching is not the more important pathway for this substances.

7. *River Quality: Phosphates and Nitrates (EA, 2012)*

Table A16 River quality classification due to phosphates and nitrates

River Quality	*Phosphates (mgP/l grade limit)*	*Nitrate (mgNO3/l grade limit)*
Very Low	0.02	5
Low	0.06	10
Moderate	0.1	20
High	0.2	30
Very High	1.0	40
Excessively High	>1.0	>40

8. *River Quality: Specific Pollutant (EA, 2012; WFD,2000/60/EC)*

Table A17 River quality definition and classification for specific pollutants

River Quality Status	Definition
High	Concentrations close to zero and at least below the limits of detection of the most advanced analytical techniques in general use, for synthetic pollutants. Concentrations within the normally range associated with undisturbed conditions, for non-synthetic pollutants.
Good	Concentrations not in excess of the standards set in accordance with the procedure detailed in section 1.2.6 without prejudice to Directive 91/414/EC and Directive 98/8/EC. (<Environmental Quality Standard)
Moderate	Conditions consistent with the achievement of the values specified in table 1.2.1. in Directive 2000/60/EC.

9. *River Quality: Specific Pollutant (phosphates) (EA, 2012; WFD, 2000/60/EC)*

Table A18 River quality for phosphates as an specific pollutant

River Quality Status	Definition
High	There are no, or only very minor, anthropogenic alterations to the values of the physic-chemical and hydromorphical quality elements for the surface water body type from those normally associated with that type under undisturbed conditions. The values of the biological quality elements for the surface water body reflect those normally associated with that type under undisturbed conditions, and show no, or only very minor, evidence of distortion.
Good	The values of the biological quality elements for the surface water body type shows low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with that type under undisturbed conditions.
Moderate	The values of the biological quality elements for the surface water body type deviate moderately from those normally associated with that type under undisturbed conditions. The values show moderate signs of distortion resulting from human activity and are significantly more disturbed than under conditions of good status.
Poor/Bad	Waters achieving a status below moderate shall be classified as poor or bad.

2. Reclassifying criteria based on land use

Table A19 Corine land uses classified by general groups

Group Land Use		Corine Specific Land Use
Arable		Non-irrigated arable land
Pasture		Heterogeneous agricultural areas Pastures
Woodland and semi-natural vegetation		Broad-leaved forest; Coniferous forest Mixed forest; Transitional woodland-shrub
Urban	Impervious	Airports; Construction sites Dump sites; Mineral extraction sites
	Open Spaces	Green urban areas Sport and leisure facilities
	Residential	Discontinuous urban fabric
	Industrial/Commercial	Industrial or commercial units
Water		Water bodies

Table A20 Criteria for risk presence depending on the current land use

Land use \ Pollutant		Phosphate	Nitrate	Pesticides	Sediments
Arable		√ fertilizers	√ fertilizers	√	√ erosion
Pasture		√ fertilizers	√ fertilizers	X	√ erosion
Semi-natural vegetation			X	X	√ erosion
Urban	Airports	√ soaps, sewage, etc.	X	X	√ erosion
	Construction sites	X	X	X	√ erosion
	Dump sites	X	X	X	√ erosion
	Mineral extraction sites	X	X	X	√ erosion
	Green urban areas	√ soaps, sewage, etc.	√ fertilizers	√ gardens, parks, etc.	√ erosion
	Sport and leisure facilities	X	√ fertilizers, sewage, etc.	√ sports grounds	√ erosion
	Discontinuous urban fabric	√ soaps, sewage, etc.	√ fertilizers sewage, etc.	√ gardens	√ erosion
	Industrial or commercial units	√ soaps, sewage, etc.	√ fertilizers sewage, etc.	X	√ erosion
Water		X	X	X	X

Table A21 Risk depending on the current land use for leaching risk model

Layer	Risk depending on land use
Pesticide leaching risk	Existing on arable and some urban uses (sports/leisure, green areas, discontinuous urban fabric) In woodland, pasture, water and some urban uses (industrial/commercial, airport, mineral extraction sites, construction sites and dump) risk it is null.
Nitrate leaching risk	Existing on arable, pasture and some urban uses (sports/leisure, green areas, discontinuous urban fabric, industrial/commercial) In semi-natural vegetation, water and some urban uses (Airport, mineral extraction sites, Construction sites and Dump) risk it is null.
Other pollutants leaching (e.g.phosphates)	Existing on arable, pasture and some urban uses (airports, sports/leisure, green areas, discontinuous urban fabric, industrial/commercial) Null risk for woodland, water and some urban uses (mineral extraction sites, dump and construction sites).

Table A22 Risk depending on the current land use for runoff risk model

Layer	Risk depending on land use
Sediments overland flow Risk	Existing on all land uses except water (risk = 0)
Phosphate overland flow risk (adsorbed to soil particles)	Existing on arable, pasture and some urban uses (airports, sports/leisure, green areas, discontinuous urban fabric, industrial/commercial) Null risk for woodland, water and some urban uses (mineral extraction sites, dump and construction sites)
Pesticide overland flow risk	Existing on arable and some urban uses (sports/leisure, green areas, discontinuous urban fabric) In woodland, pasture, water and some urban uses (industrial/commercial, airport, mineral extraction sites, construction sites and dump) risk it is null.

Appendix B: Additional Soil Carbon Results

B1: Summary of Land Use and Total SOC (0-150cm) in Central Bedfordshire

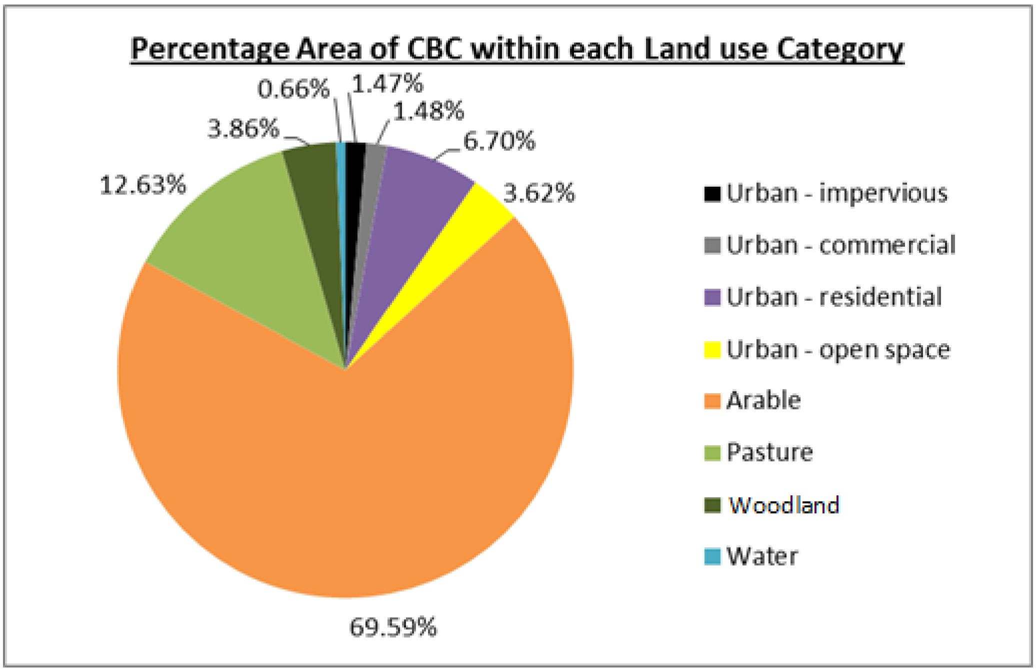

Figure B1 Percentage area of Central Bedfordshire within each land use category

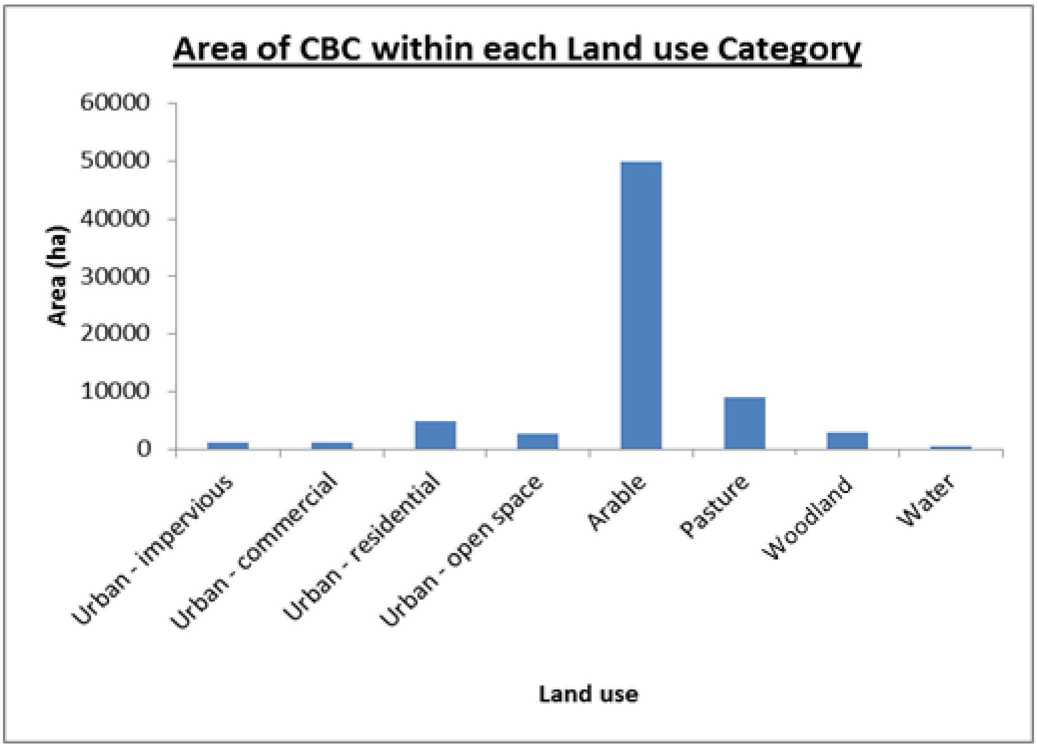

Figure B2 Area of Central Bedfordshire within each land use category

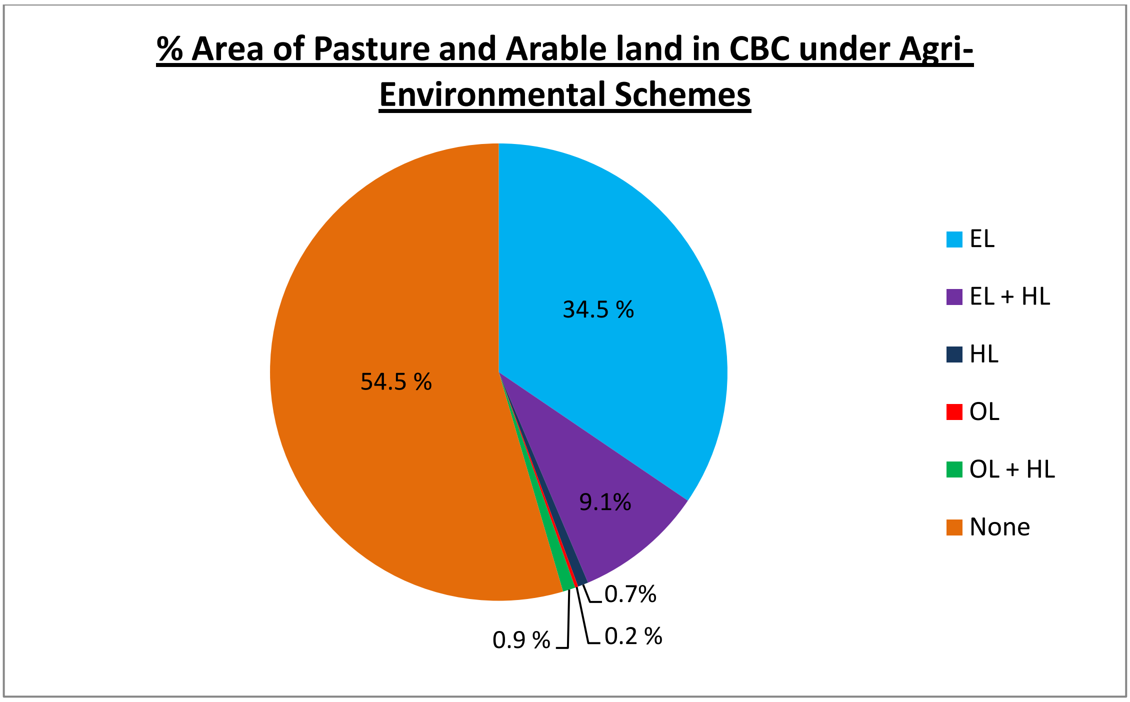

Figure B3 Percentage area of pasture and arable land in Central Bedfordshire under Agri-Environmental Scheme (EL: Entry level; HL: High level and OL: Organic level)

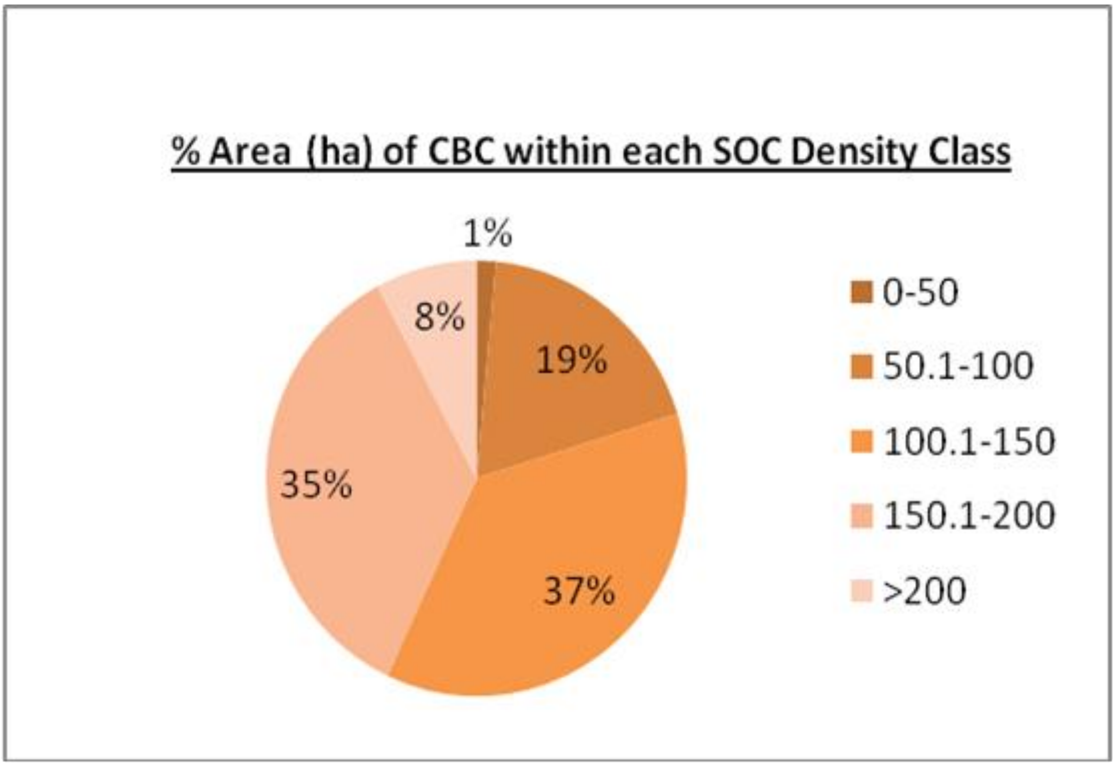

Figure B4 Percentage area of Central Bedfordshire within each SOC density (t ha^{-1}) class in the profile 0-150 cm (excludes water bodies).

B2: Maps with Land Use and SOC Data combined

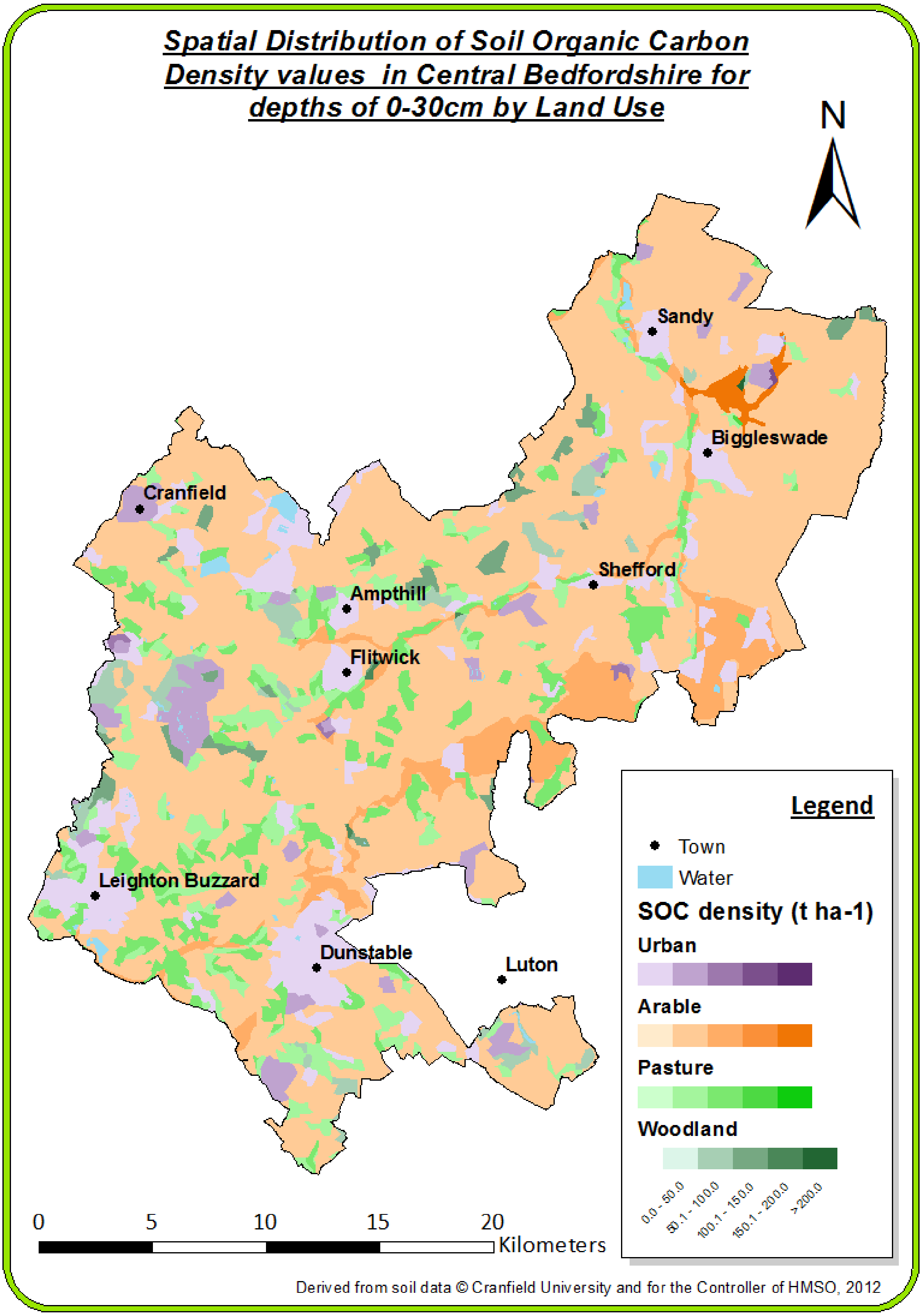

Figure B5 Spatial distribution of SOC density in Central Bedfordshire for depths of 0-30 cm by land use

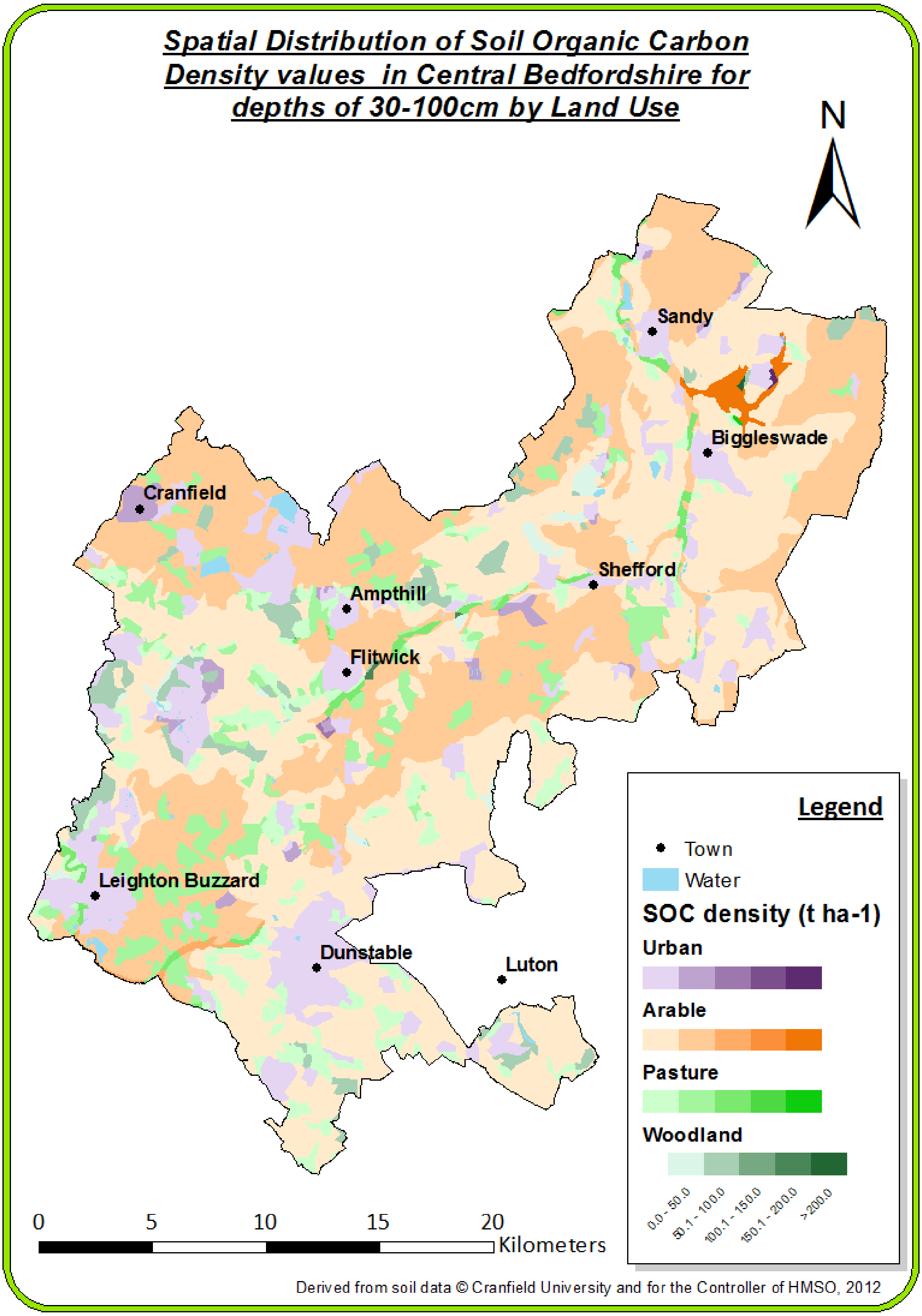

Figure B6 Spatial distribution of SOC density in Central Bedfordshire for depths of 30-100 cm by land use

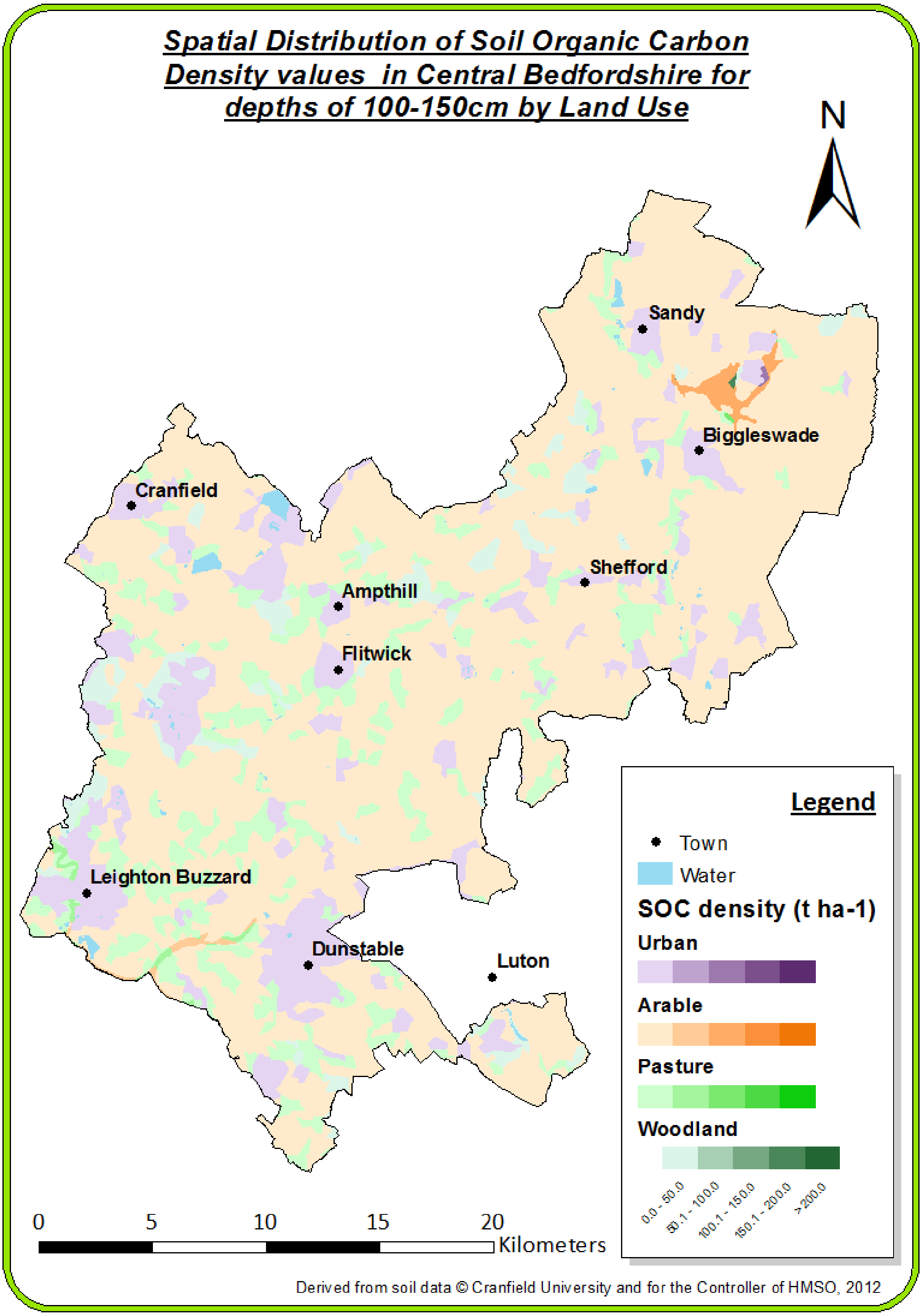

Figure B7 Spatial distribution of SOC density in Central Bedfordshire for depths of 100-150 cm by land use

B3: Results Tables

Soil carbon storage in different soil types under arable land use

Table B1 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under arable land use at depth **0-30cm** (EL: Entry level; HL: High level and OL: Organic level environmental stewardship schemes)

Soil type	Agri-Environment Scheme					
	none	EL	HL	EL+HL	OL	OL+HL
Deep clay	88.33 (82.10,90.60)	87.68 (82.10,90.60)	83.81 (82.10,90.60)	86.19 (82.10,90.60)		90.21 (82.10,90.60)
Deep loam	74.04 (69.90,75.10)	74.29 (69.90,75.10)		73.90 (73.90,73.90)		
Deep loam over gravel	58.63 (57.20,59.50)	58.40 (57.20,59.50)	59.50 (57.20,59.50)	59.00 (57.20,59.50)		
Deep loam to clay	61.72 (58.10,82.00)	62.21 (58.10,82.00)	58.54 (58.10,60.80)	60.16 (58.10,82.00)	58.1 (58.10,58.10)	60.80 (60.80,60.80)
Deep sandy	66.50 (66.50,66.50)	66.50 (66.50,66.50)	66.50 (66.50,66.50)	66.50 (66.50,66.50)		
Deep silty to clay	70.80 (70.80,70.80)	70.80 (70.80,70.80)		70.80 (70.80,70.80)		
Loam over chalk	83.26 (69.70,85.30)	84.94 (69.70,85.30)		85.30 (85.30,85.30)		85.30 (85.30,85.30)
Loam over red sandstone	59.50 (59.50,59.50)	59.50 (59.50,59.50)	59.50 (59.50,59.50)	59.50 (59.50,59.50)		59.50 (59.50,59.50)
Seasonally wet deep clay	106.20 (69.20,141.20)	90.47 (69.20,141.20)	141.20 (141.20,141.20)	127.62 (83.00,141.20)		69.20 (69.20,69.20)
Seasonally wet deep peat to loam	225.60 (225.60,225.60)	225.60 (225.60,225.60)		225.60 (225.60,225.60)		
Seasonally wet loam over gravel	89.20 (89.20,89.20)	89.20 (89.20,89.20)		89.20 (89.20,89.20)		
Shallow silty over chalk	120.12 (85.90,130.70)	120.06 (85.90,130.70)	87.80 (87.80,87.80)	101.93 (87.80,130.70)		90.03 (87.80,130.70)
Silty over chalk	88.50 (88.50,88.50)	88.50 (88.50,88.50)			88.50 (88.50,88.50)	

Table B2 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under arable land use at depth **30-100cm** (EL: Entry level; HL: High level and OL: Organic level environmental stewardship schemes)

Soil type	Agri-Environment Scheme					
	none	EL	HL	EL+HL	OL	OL+HL
Deep clay	63.87 (51.70,68.30)	62.61 (51.70,68.30)	55.03 (51.70,68.30)	59.68 (51.70,68.30)		67.55 (51.70,68.30)
Deep loam	37.42 (34.70,54.30)	36.57 (34.70,54.30)		34.70 (34.70,34.70)		
Deep loam over gravel	32.90 (31.20,35.70)	33.36 (31.20,35.70)	31.20 (31.20,35.70)	32.06 (31.20,35.70)		
Deep loam to clay	43.57 (41.00,49.30)	43.89 (41.00,47.60)	45.02 (41.00,45.80)	42.42 (41.00,47.60)	45.80 (45.80,45.80)	41.00 (41.00,41.00)
Deep sandy	29.00 (29.00,29.00)	29.00 (29.00,29.00)	29.00 (29.00,29.00)	29.00 (29.00,29.00)		
Deep silty to clay	27.60 (27.60,27.60)	27.60 (27.60,27.60)		27.60 (27.60,27.60)		
Loam over chalk	20.70 (20.20,24.00)	20.29 (20.20,24.00)		20.20 (20.20,20.20)		20.20 (20.20,20.20)
Loam over red sandstone	32.00 (32.00,32.00)	32.00 (32.00,32.00)	32.00 (32.00,32.00)	32.00 (32.00,32.00)		32.00 (32.00,32.00)
Seasonally wet deep clay	69.10 (40.10,103.00)	57.17 (40.10,103.00)	88.30 (88.30,88.30)	81.34 (56.60,103.00)		40.10 (40.10,40.10)
Seasonally wet deep peat to loam	300.90 (300.90,300.90)	300.90 (300.90,300.90)		300.90 (300.90,300.90)		
Seasonally wet loam over gravel	42.25 (42.50,42.50)	42.50 (42.50,42.50)		42.50 (42.50,42.50)		
Shallow silty over chalk	10.52 (5.90,12.40)	10.55 (5.90,12.40)	5.90 (5.90,5.90)	7.86 (5.90,12.40)		6.18 (5.90,12.40)
Silty over chalk	48.50 (48.50,48.50)	48.50 (48.50,48.50)			48.50 (48.50,48.50)	

Table B3 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under arable land use at depth **100-150cm** (EL: Entry level; HL: High level and OL: Organic level environmental stewardship schemes)

Soil type	Agri-Environment Scheme					
	none	**EL**	**HL**	**EL+HL**	**OL**	**OL+HL**
Deep clay	26.43 (22.10,26.80)	26.26 (22.10,26.80)	25.76 (25.50,26.80)	26.12 (25.50,26.80)		26.74 (25.50,26.80)
Deep loam	14.43 (9.40,16.00)	14.49 (9.4,16.00)		9.40 (9.40,9.40)		
Deep loam over gravel	5.09 (3.70,7.40)	5.47 (3.70,7.40)	3.70 (3.70,7.40)	4.41 (3.70,7.40)		
Deep loam to clay	12.34 (5.10,17.10)	11.86 (6.90,17.10)	8.57 (6.90,17.10)	14.14 (6.90,17.10)	6.90 (6.90,6.90)	17.10 (17.10,17.10)
Deep sandy	2.60 (2.60,2.60)	2.60 (2.60,2.60)	2.60 (2.60,2.60)	2.60 (2.60,2.60)		
Deep silty to clay	6.40 (6.40,6.40)	6.40 (6.40,6.40)		6.40 (6.40,6.40)		
Loam over chalk	1.31 (0.90,4.00)	0.97 (0.90,4.00)		0.90 (0.90,0.90)		0.90 (0.90,0.90)
Loam over red sandstone	6.10 (6.10,6.10)	6.10 (6.10,6.10)	6.10 (6.10,6.10)	6.10 (6.10,6.10)		6.10 (6.10,6.10)
Seasonally wet deep clay	25.97 (14.40,79.70)	26.46 (14.40,79.70)	34.00 (34.00,34.00)	30.51 (14.40,79.70)		19.60 (19.60,19.60)
Seasonally wet deep peat to loam	137.70 (137.70,137.70)	137.70 (137.70,137.70)		137.70 (137.70,137.70)		
Seasonally wet loam over gravel	4.10 (4.10,4.10)	4.10 (4.10,4.10)		4.10 (4.10,4.10)		
Shallow silty over chalk	3.25 (0.90,4.40)	3.26 (0.90,4.40)	0.90 (0.90,0.90)	1.92 (0.90,4.40)		1.04 (0.90,4.40)
Silty over chalk	10.50 (10.50,10.50)	10.50 (10.50,10.50)			10.50 (10.50,10.50)	

Table B4 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under arable land use at total depth **0-150cm** (EL: Entry level; HL: High level and OL: Organic level environmental stewardship schemes)

Soil type	Agri-Environment Scheme					
	none	EL	HL	EL+HL	OL	OL+HL
Deep clay	178.62 (159.30,185.70)	176.55 (159.30,185.70)	164.60 (159.30,185.70)	171.99 (159.30,185.70)		184.50 (159.30,185.70)
Deep loam	125.89 (118.00,137.70)	125.34 (118.00,137.70)		118.00 (118.00,118.00)		
Deep loam over gravel	96.62 (94.40,100.30)	97.23 (94.40,100.30)	94.40 (94.40,100.30)	95.53 (94.40,100.30)		
Deep loam to clay	117.64 (110.80,140.10)	117.96 (110.80,140.10)	112.12 (110.80,118.90)	116.71 (110.80,140.10)	110.80 (110.80,110.80)	118.90 (118.90,118.90)
Deep sandy	98.10 (98.10,98.10)	98.10 (98.10,98.10)	98.10 (98.10,98.10)	98.10 (98.10,98.10)		
Deep silty to clay	104.80 (104.80,104.80)	104.80 (104.80,104.80)		104.80 (104.80,104.80)		
Loam over chalk	105.26 (97.70,106.40)	106.20 (97.70,106.40)		106.40 (106.40,106.40)		106.40 (106.40,106.40)
Loam over red sandstone	97.60 (97.60,97.60)	97.60 (97.60,97.60)	97.60 (97.60,97.60)	97.60 (97.60,97.60)		97.60 (97.60,97.60)
Seasonally wet deep clay	201.27 (128.90,314.30)	174.10 (128.90,314.30)	263.50 (263.50,263.50)	239.47 (154.00,314.30)		128.90 (128.90,128.90)
Seasonally wet deep peat to loam	664.40 (664.20,664.20)	664.20 (664.20,664.20)		664.20 (664.20,664.20)		
Seasonally wet loam over gravel	135.80 (135.80,135.80)	135.80 (135.80,135.80)		135.80 (135.80,135.80)		
Shallow silty over chalk	133.90 (94.60,147.50)	133.88 (94.60,147.50)	94.60 (94.60,94.60)	111.71 (94.60,147.50)		97.24 (94.60,147.50)
Silty over chalk	147.50 (147.50,147.50)	147.50 (147.50,147.50)			147.50 (147.50,147.50)	

Soil carbon storage in different soil types under pasture

Table B5 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under pasture land use at depth **0-30cm** (EL: Entry level; HL: High level and OL: Organic level environmental stewardship schemes)

Soil type	Agri-Environment Scheme					
	none	EL	HL	EL+HL	OL	OL+HL
Deep clay	100.67 (91.90,112.80)	100.91 (91.9,112.80)	101.88 (91.90,104.00)	100.196 (91.90,104.00)		102.90 (91.90,104.00)
Deep loam	97.66 (84.10,103.10)	99.00 (84.10,103.10)		99.30 (99.30,99.30)		
Deep loam over gravel	77.97 (74.00,83.20)	76.36 (74.00,83.20)	74.00 (74.00,74.00)	74.27 (74.00,83.20)		
Deep loam to clay	91.93 (76.10,100.90)	92.79 (76.10,113.50)	76.10 (76.10,76.10)	96.12 (76.10,100.9)	76.1 (76.10,7.10)	100.90 (100.90,100.90)
Deep sandy	77.00 (77.00,77.00)	77.00 (77.00,77.00)	77.00 (77.00,77.00)	77.00 (77.00,77.00)		
Deep silty to clay	86.80 (86.80,86.80)	86.80 (86.80,86.80)			86.8 (86.80,86.80)	
Loam over chalk	89.60 (75.20,93.60)	93.49 (75.20,93.60)				93.60 (93.60,93.60)
Loam over red sandstone	76.50 (76.50,76.50)	76.5 (76.50,76.50)		76.50 (76.50,76.50)		76.5 (76.50,76.50)
Seasonally wet deep clay	131.81 (97.70,140.10)	123.79 (97.70,104.10)	140.1 (140.10,140.10)	137.53 (113.70,140.10)		97.7 (97.70,97.70)
Seasonally wet deep peat to loam	195.20 (195.2,195.2)			195.20 (195.20,195.20)		
Seasonally wet loam over gravel						
Shallow silty over chalk	113.86 (1409.10,129.90)	114.76 (109.10, 129.9)	109.1 (109.10,109.10)	113.23 (109.10,129.90)		109.26 (109.10,129.90)
Silty over chalk	101.30 (101.30,101.30)	101.3 (101.30, 101.30)			101.3 (101.30,101.30)	

Table B6 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under pasture land use at depth **30-100cm** (EL: Entry level; HL: High level and OL: Organic level environmental stewardship schemes)

Soil type	Agri-Environment Scheme					
	none	EL	HL	EL+HL	OL	OL+HL
Deep clay	69.38 (60.60,75.50)	69.81 (60.60,75,50)	70.91 (60.6,73.10)	69.17 (60.60,73.10)		71.96 (60.60,73.10)
Deep loam	42.51 (40.40,49.70)	43.53 (40.40,49.70)		40.4 (40.40,40.40)		
Deep loam over gravel	35.40 (35.10,35.80)	35.28 (35.10,35.80)	35.10 (35.10,31.50)	35.12 (35.10,35.80)		
Deep loam to clay	52.78 (48.70,56.10)	52.96 (48.70,56.10)	48.70 (48.70,48.70)	54.67 (48.70,56.10)	48.70 (48.70,48.70)	56.1 (56.10,56.10)
Deep sandy	44.70 (44.70,44.70)	44.70 (44.70,44.70)	44.70 (44.70,44.70)	44.7 (44.70,44.70)		
Deep silty to clay	29.40 (29.4,29.4)	29.40 (29.40,29.40)			29.40 (29.40,29.40)	
Loam over chalk	21.16 (20.20,24.60)	20.23 (20.20,24.60)				20.20 (20.20,20.20)
Loam over red sandstone	39.00 (39.00,39.00)	39.00 (39.00,39.00)		39.00 (39.00,39.00)		39.00 (39.00,39.00)
Seasonally wet deep clay	112.35 (46.60,130.80)	96.96 (46.60,130.80)	130.8 (130.80,130.80)	122.61 (70.80,130.80)		46.60 (46.60,46.60)
Seasonally wet deep peat to loam	274.70 (274.70,274.70)			274.70 (274.70,274.70)		
Seasonally wet loam over gravel						
Shallow silty over chalk	8.06 (5.90,15.80)	8.58 (5.90,15.8)	5.90 (5.90,5.90)	7.11 (5.90,12.00)		5.96 (5.90,15.80)
Silty over chalk	49.30 (49.30,49.30)	49.30 (49.30,49.30)			49.3 (49.30,49.3)	

Table B7 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under pasture land use at depth **100-150cm** (EL: Entry level; HL: High level and OL: Organic level environmental stewardship schemes)

Soil type	Agri-Environment Scheme					
	none	EL	HL	EL+HL	OL	OL+HL
Deep clay	26.22 (22.40,26.80)	26.39 (22.40,26.80)	26.57 (25.50,26.80)	26.39 (25.50,26.80)		26.68 (25.50,26.80)
Deep loam	11.07 (9.40,17.00)	11.01 (9.40,17.00)		9.40 9.40,9.40		
Deep loam over gravel	4.53 (4.10,5.10)	4.36 (4.10,5.10)	4.10 (4.10,4.10)	4.13 (4.10,5.10)		
Deep loam to clay	12.25 (5.10,17.90)	12.43 (6.90,17.90)	6.90 (6.90,6.90)	15.78 (6.90,17.90)	6.90 (6.90,6.90)	17.90 (17.90,17.90)
Deep sandy	2.60 (2.60,2.60)	2.60 (2.60,2.60)	2.60 (2.60,2.60)	2.60 (2.60,2.60)		
Deep silty to clay	6.40 (6.40,6.40)	6.40 (6.40,6.40)			6.40 (6.40,6.40)	
Loam over chalk	1.57 (0.90,4.00)	0.92 (0.90,4.00)				0.90 (0.90,0.90)
Loam over red sandstone	6.10 (6.10,6.10)	6.1 (6.10,6.10)		6.10 (6.10,6.10)		6.10 (6.10,6.10)
Seasonally wet deep clay	35.53 (15.70,79.70)	38.03 (15.70,79.70)		51.69 (15.70,79.70)		21.80 (21.80,21.80)
Seasonally wet deep peat to loam	137.70 (137.70,137.70)		30.5 (30.50,30.50)	137.7 (137.70,137.70)		
Seasonally wet loam over gravel						
Shallow silty over chalk	1.64 (0.90,4.40)	1.83 (0.90,4.40)	0.90 (0.90,0.90)	1.24 (0.90,2.60)		0.92 (0.90,4.40)
Silty over chalk	10.50 (10.50,10.50)	10.50 (10.50,10.50)			10.50 (10.50,10.50)	

Table B8 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under pasture land use at total depth **0-150cm** (EL: Entry level; HL: High level and OL: Organic level environmental stewardship schemes)

Soil type	Agri-Environment Scheme					
	none	EL	HL	EL+HL	OL	OL+HL
Deep clay	196.27 (178.00,210.70)	197.11 (178.00,210.70)	199.37 (178.00,203.90)	195.76 (178.00,203.90)		201.55 (178.00,203.90)
Deep loam	151.24 (144.30,165.00)	153.53 (144.3,165.00)		149.10 (149.10,149.10)		
Deep loam over gravel	117.90 (113.20,124.10)	116.00 (113.20,124.10)	113.20 (113.20,113.20)	113.51 (113.20,124.10)		
Deep loam to clay	156.96 (131.70,179.70)	158.18 (131.70,179.70)	131.70 (131.70,131.70)	166.57 (131.70,174.90)	131.70 (131.70,131.70)	174.90 (174.90,174.90)
Deep sandy	124.30 (124.30,124.30)	124.30 (124.30,124.30)	124.30 (124.30,124.30)	124.30 (124.30,124.3)		
Deep silty to clay	122.60 (122.60,122.60)	122.60 (122.60,122.60)			122.60 (122.60,122.60)	
Loam over chalk	112.33 (103.80,114,70)	114.64 (103.80,114.70)				114.70 (114.70,114.70)
Loam over red sandstone	121.60 (121.60,121.60)	121.60 (121.60,121.60)		121.60 (121.60,121.60)		121.60 (121.60,121.60)
Seasonally wet deep clay	279.69 (166.10,332.20)	258.77 (166.10,332.20)		311.83 (200.20,332.20)		166.10 (166.10,166.10)
Seasonally wet deep peat to loam	607.60 (607.60,607.60)		301.40 (301.40,301.40)	607.60 (607.60,607.60)		
Seasonally wet loam over gravel						
Shallow silty over chalk	123.56 (115.90,150.00)	125.17 (115.90,150.00)	115.90 (115.90,115.90)	121.58 (115.90,144.50)		116.14 (115.90,150.00)

Silty over chalk	161.10 (161.10,161.10)	161.1 (161.10,161.10)			161.10 (161.10,161.10)	

Soil carbon storage in different soil types under woodland vegetation

Table B9 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under woodland at depth **0-30cm**

Soil type	woodland type			
	Broad-leaved	**Coniferous**	**Mixed**	**Transitional woodland-shrub**
Deep clay	119.38 (114.88, 130.00)	121.37 (114.88, 130.00)	125.62 (114.88, 130.00)	130 (122.13, 122.13)
Deep loam	105.13 (105.13, 105.13)	105.13 (105.13, 105.13)		
Deep loam over gravel	92.50 (92.5, 92.50)	92.5 (92.50, 92.50)		
Deep loam to clay	111.31 (95.13, 126.13)	126.13 (126.13, 126.13)		126.13 (126.13, 126.13)
Deep sandy	96.25 (96.25, 96.25)	96.25 (96.25, 96.25)		
Deep silty to clay	108.5 (108.5, 108.5)			
Loam over chalk	117 (117.00, 117.00)			117.00 (117.00, 117.00)
Loam over red sandstone	95.63 (95.63, 95.63)	95.63 (95.63, 95.63)		95.63 (95.63, 95.63)
Seasonally wet deep clay	131.19 (122.13, 175.13)	122.45 (122.13, 175.13)	142.13 (142.13, 142.13)	122.13 (112.13, 112.13)
Seasonally wet deep peat to loam	244 (244.00, 244.00)			
Seasonally wet loam over gravel				
Shallow silty over chalk	136.38 (136.38, 136.38)			147.11 (136.38, 162.38)
Silty over chalk				

Table B10 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under woodland at depth **30-100cm**

Soil type	Woodland type			
	Broad-leaved	**Coniferous**	**Mixed**	**Transitional woodland-shrub**
Deep clay	80.41 (75.75, 91.38)	82.46 (75.75, 91.38)	86.85 (75.75, 91.38)	91.38 (91.38, 91.38)
Deep loam	54.00 (54.00, 54.00)	54.00 (54.00, 54.00)		
Deep loam over gravel	43.88 (43.88, 43.88)	43.88 (43.88, 43.88)		
Deep loam to clay	65.71 (60.88, 70.13)	70.13 (70.13, 70.13)		70.13 (70.13, 70.13)
Deep sandy	55.88 (55.88, 55.88)	55.88 (55.88, 55.88)		
Deep silty to clay	36.75 (36.75, 36.75)			
Loam over chalk	25.25 (25.25, 25.25)			25.25 (25.25, 25.25)
Loam over red sandstone	48.75 (48.75, 48.75)	48.75 (75.75, 91.38)		48.75 (48.75, 48.75)
Seasonally wet deep clay	74.89 (58.25, 163.50)	58.90 (58.25, 163.50)	88.50 (88.50, 88.50)	58.25 (58.25, 58.25)
Seasonally wet deep peat to loam	343.38 (343.38, 343.38)			
Seasonally wet loam over gravel				
Shallow silty over chalk	7.38 (7.38, 7.38)			10.52 (7.38, 15.00)
Silty over chalk				

Table B11 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under woodland at depth **100-150cm**

Soil type	Woodland type			
	Broad-leaved	**Coniferous**	**Mixed**	**Transitional woodland-shrub**
Deep clay	32.36 (31.88, 33.5)	32.57 (31.88, 32.50)	33.03 (31.88, 33.50)	33.50 (33.50, 33.50)
Deep loam	21.25 (21.25, 21.25)	21.25 (21.25, 21.25)		
Deep loam over gravel	5.13 (5.13, 5.13)	5.13 (5.13, 5.13)		
Deep loam to clay	15.81 (8.63, 22.38)	22.38 (22.38, 22.38)		22.38 (22.38, 22.38)
Deep sandy	3.25 (3.25, 3.25)	3.25 (3.25, 3.25)		
Deep silty to clay	8.00 (8.00, 8.00)			
Loam over chalk	1.13 (1.13, 1.13)			1.13 (1.13, 1.13)
Loam over red sandstone	7.63 (7.63, 7.63)	7.63 (7.63, 7.63)		7.63 (7.63, 7.63)
Seasonally wet deep clay	27.42 (19.63, 38.13)	27.32 (27.25, 38.13)	19.63 (19.63, 19.63)	27.25 (27.25, 27.25)
Seasonally wet deep peat to loam	172.13 (172.13, 172.13)			
Seasonally wet loam over gravel				
Shallow silty over chalk	1.13 1.13, 1.13)			2.00 (1.13, 3.25)
Silty over chalk				

Table B12 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under woodland at total depth **0-150cm**

Soil type	Woodland type			
	Broad-leaved	Coniferous	Mixed	Transitional woodland-shrub
Deep clay	232.15 (222.50, 254.88)	236.41 (222.50, 254.88)	245.50 (222.50, 254.88)	254.88 (254.88, 254.88)
Deep loam	180.38 (180.38, 180.38)	180.38 (180.38, 180.30)		
Deep loam over gravel	141.50 (141.50, 141.50)	141.50 (141.50, 141.50)		
Deep loam to clay	192.82 (164.63, 218.63)	218.63 (218.63, 218.63)		218.63 (218.63, 218.63)
Deep sandy	155.38 (155.38, 155.38)	155.38 (155.38, 155.38)		
Deep silty to clay	153.25 (153.25, 153.25)			
Loam over chalk	143.38 (143.38, 143.38)			143.38 (143.38, 143.38)
Loam over red sandstone	152.00 (152.00, 152.00)	152.00 (152.00, 152.00)		152.00 (152.00, 152.00)
Seasonally wet deep clay	233.50 (376.75, 207.63)	208.66 (207.63, 176.75)	250.25 (250.25, 250.25)	207.63 (207.63, 207.63)
Seasonally wet deep peat to loam	759.50 (759.50, 759.50)			
Seasonally wet loam over gravel				
Shallow silty over chalk	144.88 (144.88, 144.88)			159.63 (144.88, 180.63)
Silty over chalk				

Soil carbon storage in different soil types under urban land use

Table B13 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under urban land use at depth **0-30cm**

Soil type	Urban			
	Commercial	Residential	Impervious	Open spaces
Deep clay	15.4 (13.8.16.9)	35.7 (35.2, 39.5)	0.0 (0.0, 0.0)	87.7 (82.7,93.6)
Deep loam	12.6 (12.6,12.6)	32.5 (29.4,34.8)	0.0 (0.0, 0.0)	89.4 (89.4,89.4)
Deep loam over gravel	11.1 (11.1,11.1)	26.5 (25.9,29.1)	0.0 (0.0, 0.0)	71.4 (66.6,74.9)
Deep loam to clay	16.9 (15.1.17.0)	31.5 (26.6,39.7)	0.0 (0.0, 0.0)	76.3 (68.5,102.2)
Deep sandy	11.6 (11.6,11.6)	27.0 (27.0,27.0)	0.0 (0.0, 0.0)	69.3 (69.3,69.3)
Deep silty to clay			0.0 (0.0, 0.0)	
Loam over chalk	14.0 (14.0,14.0)	32.8 (26.3,32.8)	0.0 (0.0, 0.0)	84.2 (84.2,84.2)
Loam over red sandstone	11.5 (11.5,11.5)	26.8 (26.8,26.8)	0.0 (0.0, 0.0)	68.9 (68.9,68.9)
Seasonally wet deep clay	19.2 (10.6,19.6)	44.5 (16.3,45.8)	0.0 (0.0, 0.0)	91.8 (87.9,126.1)
Seasonally wet deep peat to loam		68.3 (68.3,68.3)	0.0 (0.0, 0.0)	175.7 (175.7,175.7)
Seasonally wet loam over gravel		37.3 (37.3,37.3)	0.0 (0.0, 0.0)	
Shallow silty over chalk	17.1 (16.4,19.5)	43.1 (38.2,45.5)	0.0 (0.0, 0.0)	105.0 (98.2,116.9)
Silty over chalk		35.5 (35.5.35.5)	0.0 (0.0, 0.0)	91.2 (91.2,91.2)

Table B14 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under urban land use at depth **30-100cm**

Soil type	Urban			
	Commercial	**Residential**	**Impervious**	**Open spaces**
Deep clay	10.8 (9.1,11.3)	24.7 (21.2,26.4)	0.0 (0.0, 0.0)	59.7 (54.5,65.8)
Deep loam	6.5 (6.5,6.5)	14.5 (14.1,15.1)	0.0 (0.0, 0.0)	36.4 (36.4,36.4)
Deep loam over gravel	5.3 (5.3,5.3)	12.3 (12.2,12.5)	0.0 (0.0, 0.0)	32.0 (31.6,32.2)
Deep loam to clay	8.3 (8.2,8.4)	18.4 (17.0,19.6)	0.0 (0.0, 0.0)	45.9 (43.8,50.5)
Deep sandy	6.7 (6.7,6.7)	15.6 (15.6,15.6)	0.0 (0.0, 0.0)	40.2 (40.2,40.2)
Deep silty to clay			0.0 (0.0, 0.0)	
Loam over chalk	3.0 (3.0,3.0)	7.1 (7.0,8.6)	0.0 (0.0, 0.0)	18.2 (18.2,18.2)
Loam over red sandstone	5.9 (5.9,5.9)	13.7 (13.7,13.7)	0.0 (0.0, 0.0)	35.1 (35.1,35.1)
Seasonally wet deep clay	15.1 (10.6,19.6)	35.9 (16.3,45.8)	0.0 (0.0, 0.0)	49.6 (41.9,117.72)
Seasonally wet deep peat to loam		96.1 (96.1.96.1)	0.0 (0.0, 0.0)	247.2 (247.2,247.2)
Seasonally wet loam over gravel		15.4 (15.4,15.4)	0.0 (0.0, 0.0)	
Shallow silty over chalk	1.2 (0.9,2.4)	4.3 (2.1,5.5)	0.0 (0.0, 0.0)	8.5 (5.3,14.2)
Silty over chalk		17.3 (17.3,17.3)	0.0 (0.0, 0.0)	44.4 (44.4,44.4)

Table B15 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under urban land use at depth **100-150cm**

Soil type	Urban			
	Commercial	Residential	Impervious	Open spaces
Deep clay	4.0 (3.4,4.0)	9.2 (7.8,9.4)	0.0 (0.0, 0.0)	23.5 (23.0,24.1)
Deep loam	2.6 (2.6,2.6)	4.4 (3.3,6.0)	0.0 (0.0, 0.0)	8.5 (8.5,8.5)
Deep loam over gravel	0.6 (0.6,0.6)	1.5 (1.4,1.8)	0.0 (0.0, 0.0)	4.2 (3.7,4.6)
Deep loam to clay	1.7 (1.7,2.7)	4.2 (2.4,6.3)	0.0 (0.0, 0.0)	9.0 (6.2,16.1)
Deep sandy	0.4 (0.4,0.4)	0.9 (0.9,0.9)	0.0 (0.0, 0.0)	2.3 (2.3,2.3)
Deep silty to clay	-	-	0.0 (0.0, 0.0)	-
Loam over chalk	0.1 (0.1,0.1)	0.3 (0.3,1.4)	0.0 (0.0, 0.0)	0.8 (0.8,0.8)
Loam over red sandstone	0.9 (0.9,0.9)	2.1 (2.1,2.1)	0.0 (0.0, 0.0)	5.5 (5.5,5.5)
Seasonally wet deep clay	6.1 (2.4,12.0)	12.7 (5.5,27.9)	0.0 (0.0, 0.0)	20.4 (19.6,27.5)
Seasonally wet deep peat to loam	-	48.2 (48.2,48.2)	0.0 (0.0, 0.0)	123.9 (123.9,123.9)
Seasonally wet loam over gravel	-	1.4 (1.4,1.4)	0.0 (0.0, 0.0)	-
Shallow silty over chalk	0.3 (0.1,0.7)	1.1 (0.3,1.5)	0.0 (0.0, 0.0)	1,9 (0.8,4.0)
Silty over chalk	-	3.7 (3.7.3.7)	0.0 (0.0, 0.0)	9.5 (9.5,9.5)

Table B16 Mean, minimum and maximum values of soil carbon density (t ha^{-1}) in different soil types under urban land use at total depth **0-150cm**

Soil type	Urban			
	Commercial	**Residential**	**Impervious**	**Open spaces**
Deep clay	30.2 (26.7,31.6)	69.7 (62.3,73.7)	0.0 (0.0, 0.0)	170.9 (160.2,183.5)
Deep loam	21.6 (21.6.21.6)	51.5 (50.5,52.2)	0.0 (0.0, 0.0)	134.2 (134.2,134.2)
Deep loam over gravel	17.0 (17.0,17.0)	40.4 (39.6.43.4)	0.0 (0.0, 0.0)	107.6 (101.9,111.7)
Deep loam to clay	26.9 (26.2,27.0)	54.1 (46.1,62.9)	0.0 (0.0, 0.0)	131.1 (118.5,161.7)
Deep sandy	18.6 (18.6,18.6)	43.5 (43.5,43.5)	0.0 (0.0, 0.0)	111.9 (111.9,111.9)
Deep silty to clay			0.0 (0.0, 0.0)	
Loam over chalk	17.2 (17.2,17.2)	40.1 (36.3,40.1)	0.0 (0.0, 0.0)	103.2 (103.2,103.2)
Loam over red sandstone	18.2 (18.2,18.2)	42.6 (42.6,42.6)	0.0 (0.0, 0.0)	109.4 (109.4,109.4)
Seasonally wet deep clay	40.4 (30.0,49.8)	93.1 (58.1,116.3)	0.0 (0.0, 0.0)	161.9 (149.5,271.3)
Seasonally wet deep peat to loam		212.7 (212.7,212.7)	0.0 (0.0, 0.0)	115.4 (104.3,135.0)
Seasonally wet loam over gravel		54.2 (54.2,54.2)	0.0 (0.0, 0.0)	
Shallow silty over chalk	18.6 (17.4,22.5)	48.5 (40.6,52.5)	0.0 (0.0, 0.0)	115.4 (104.3,135.0)
Silty over chalk		56.4 (56.4,56.4)	0.0 (0.0, 0.0)	145.0 (145.0,145.0)

Appendix C: Additional Run-off Results

C1: Scenario Maps

1. **Scenario 1: Urban development**

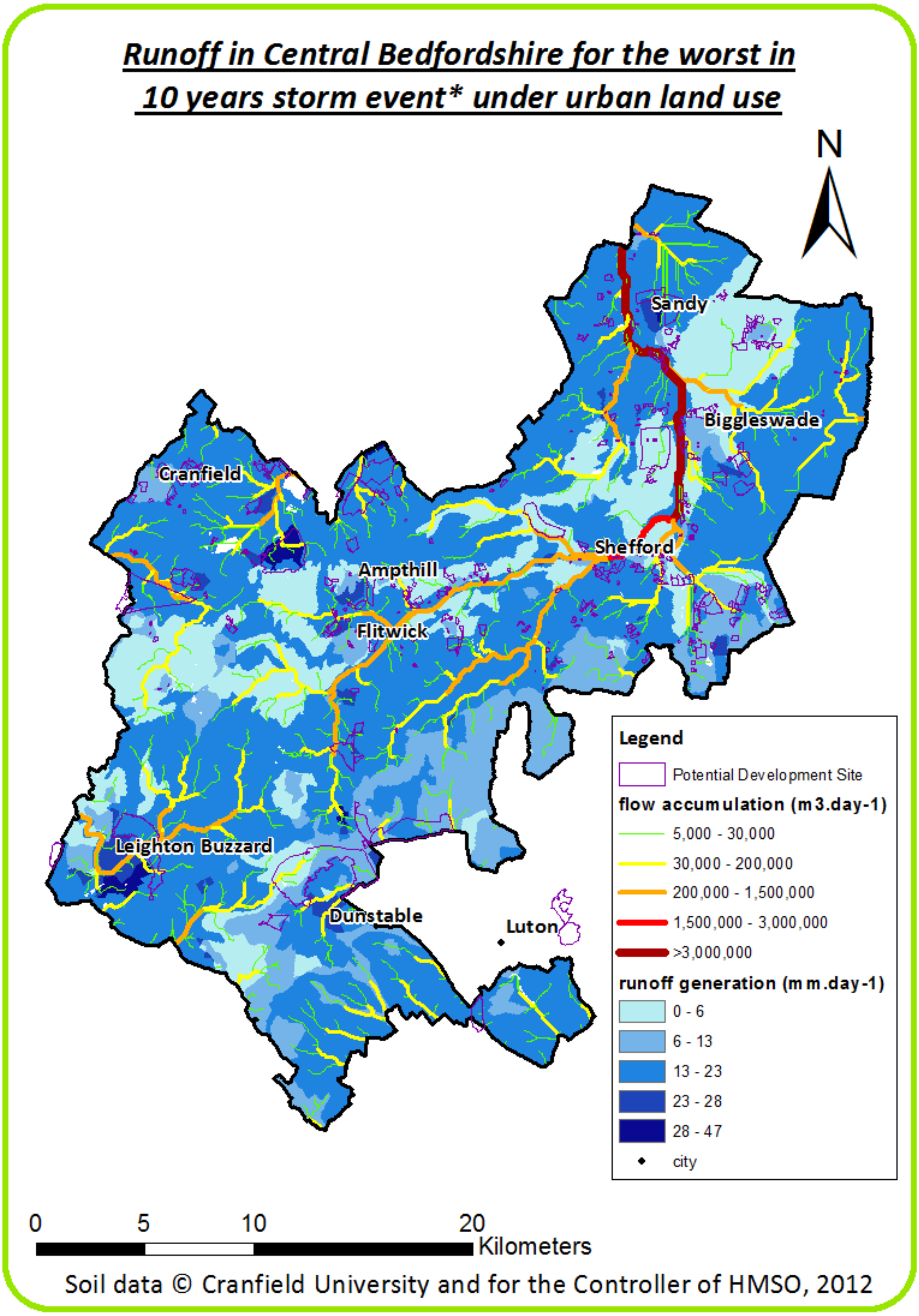

Figure C1. Predicted runoff in Central Bedfordshire for the 1 in 10 years storm event under urban land use. Previous soil wetness was assumed to be intermediate. Potential development sites proposed by CBC are shown in the map.

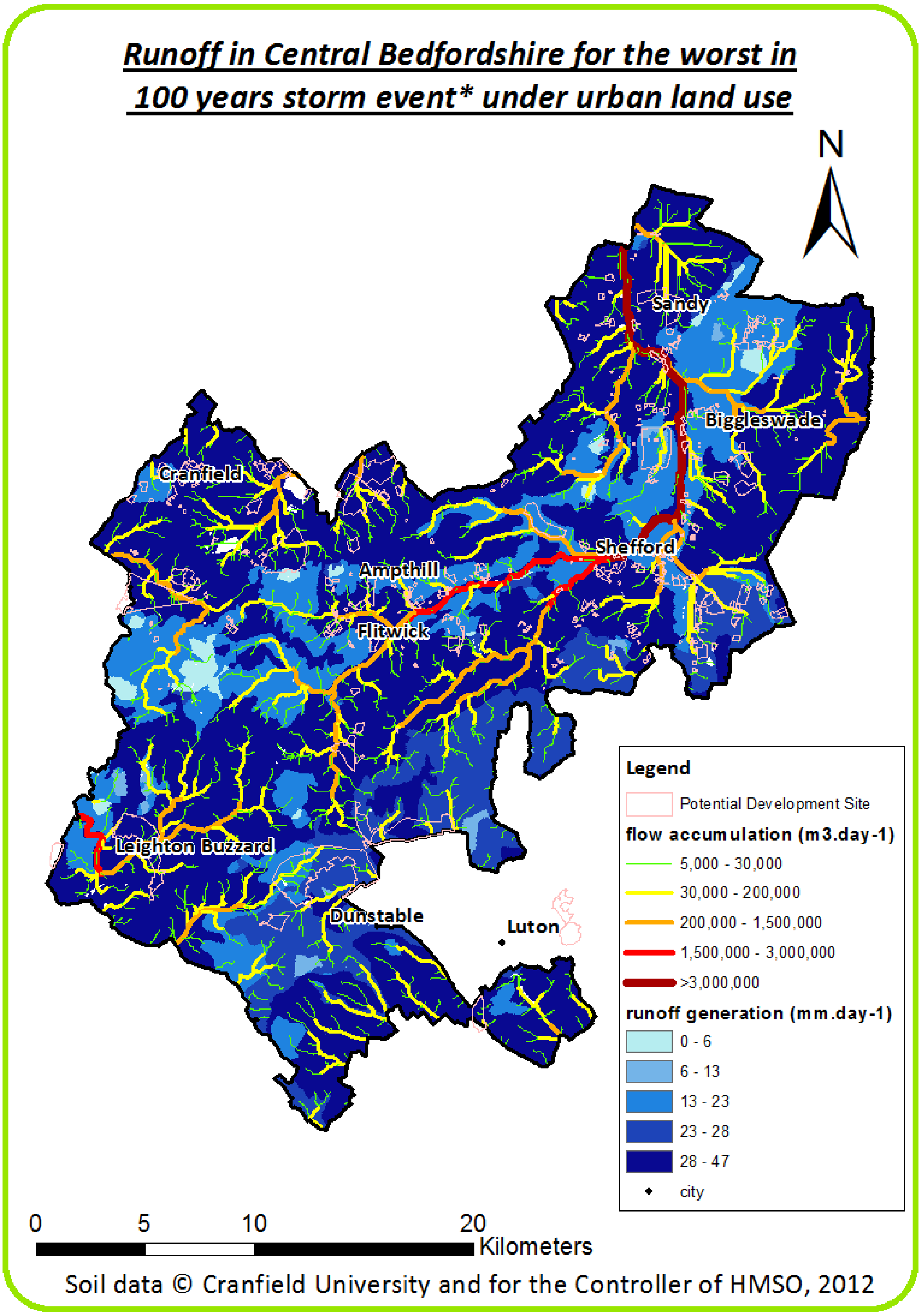

Figure C2. Predicted runoff in Central Bedfordshire for the 1 in 100 years storm event under urban land use. Previous soil wetness was assumed to be intermediate. Potential development sites proposed by CBC are shown in the map.

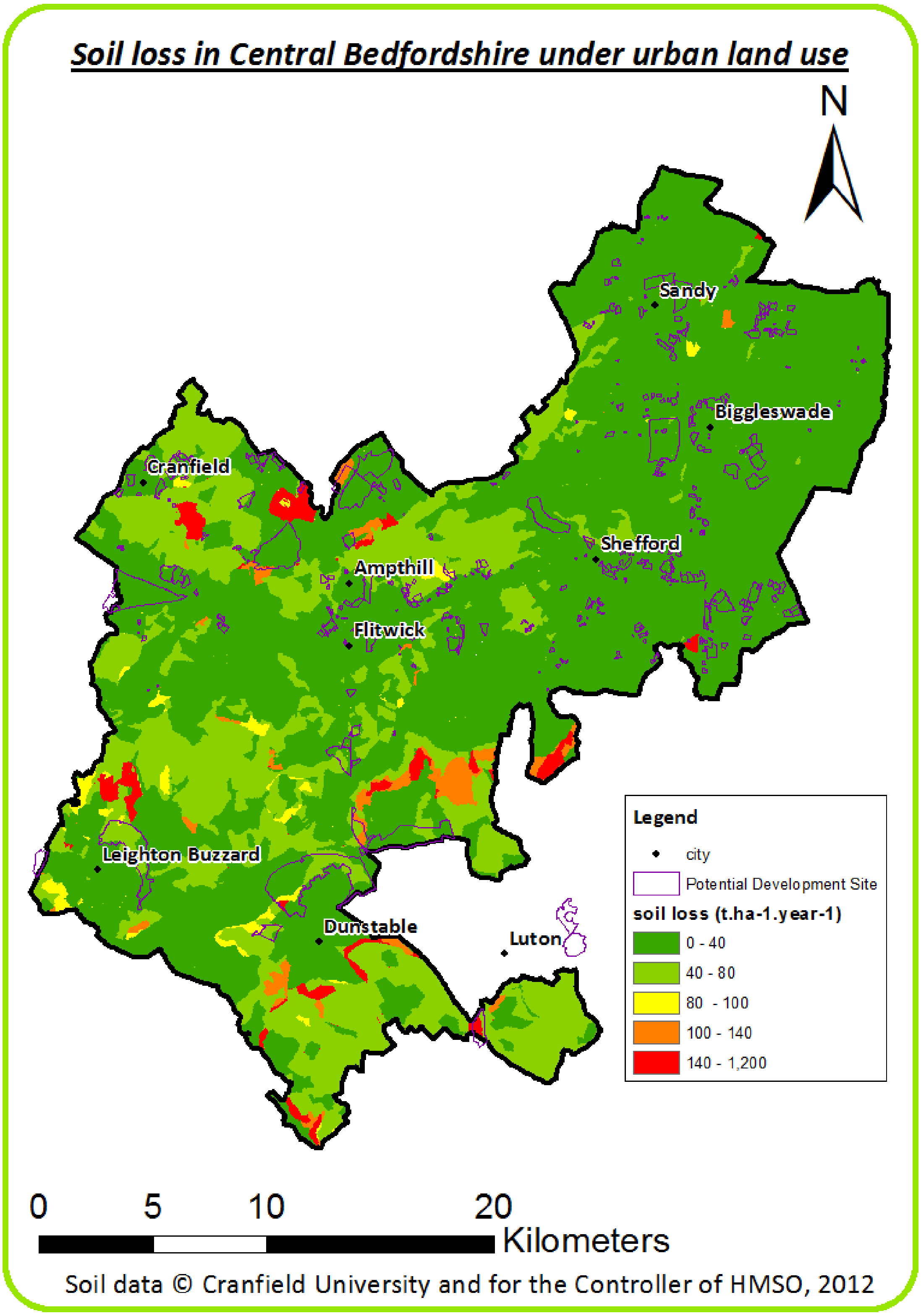

Figure C3. Predicted soil loss in Central Bedfordshire County under urban land use. Potential development sites proposed by CBC are shown in the map.

2. Scenario 2: Woodland land use

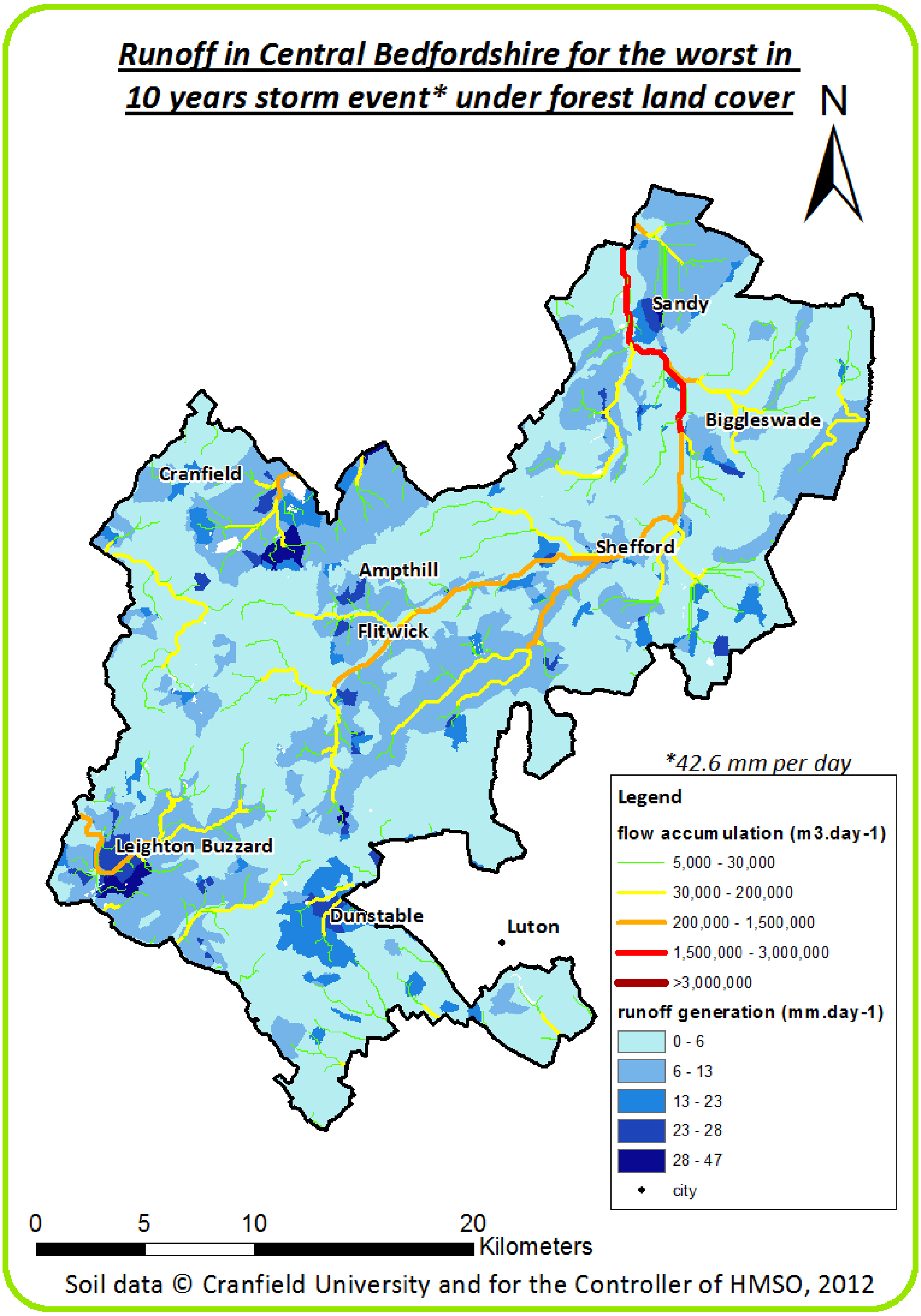

Figure C4. Predicted runoff in Central Bedfordshire for the 1 in 10 years storm event under woodland land use. Previous soil wetness was assumed to be intermediate. Current urban areas stay as urban areas in this scenario.

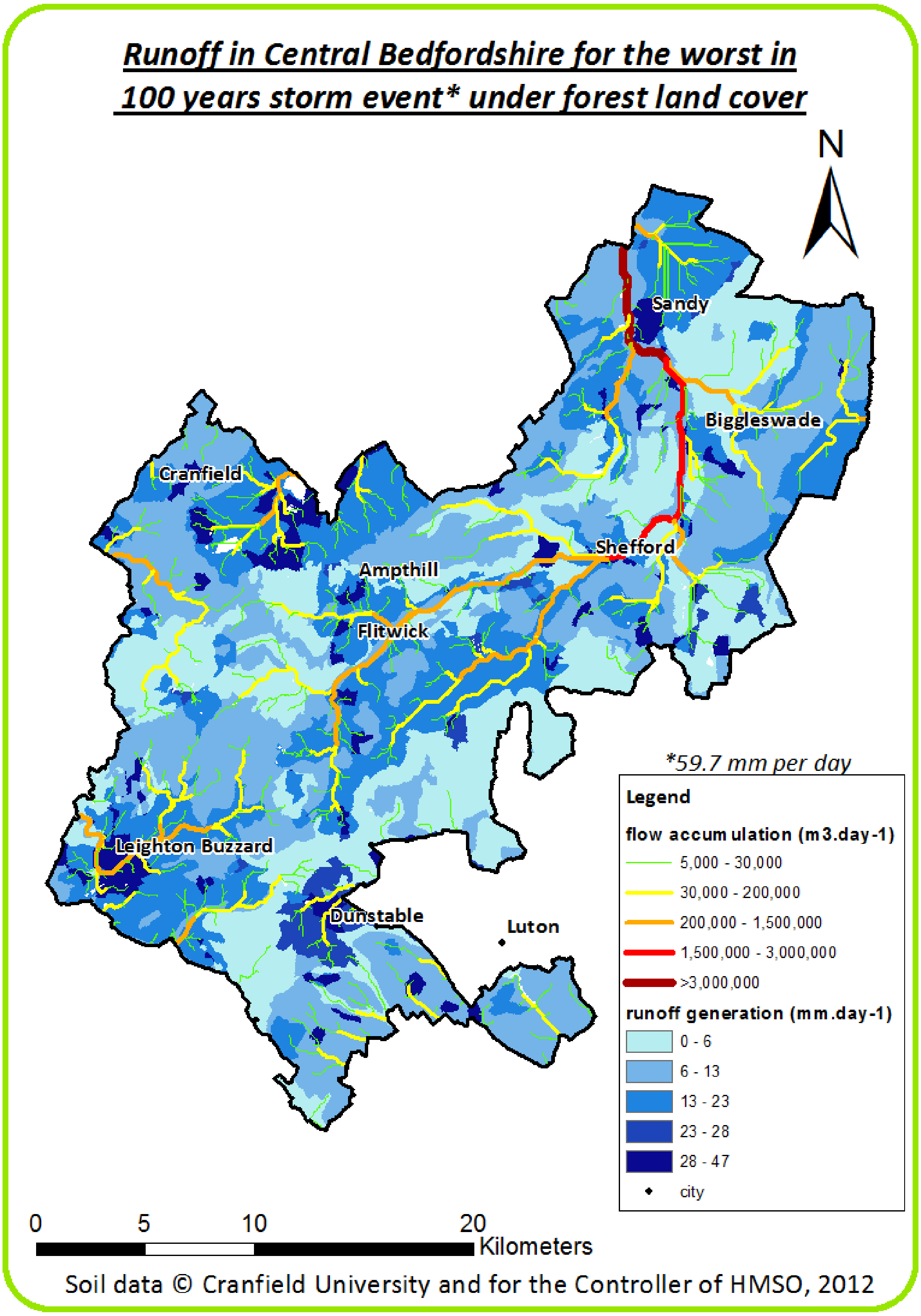

Figure C5. Predicted runoff in Central Bedfordshire for the 1 in 100 years storm event under woodland land use. Previous soil wetness was assumed to be intermediate. Current urban areas stay as urban areas in this scenario.

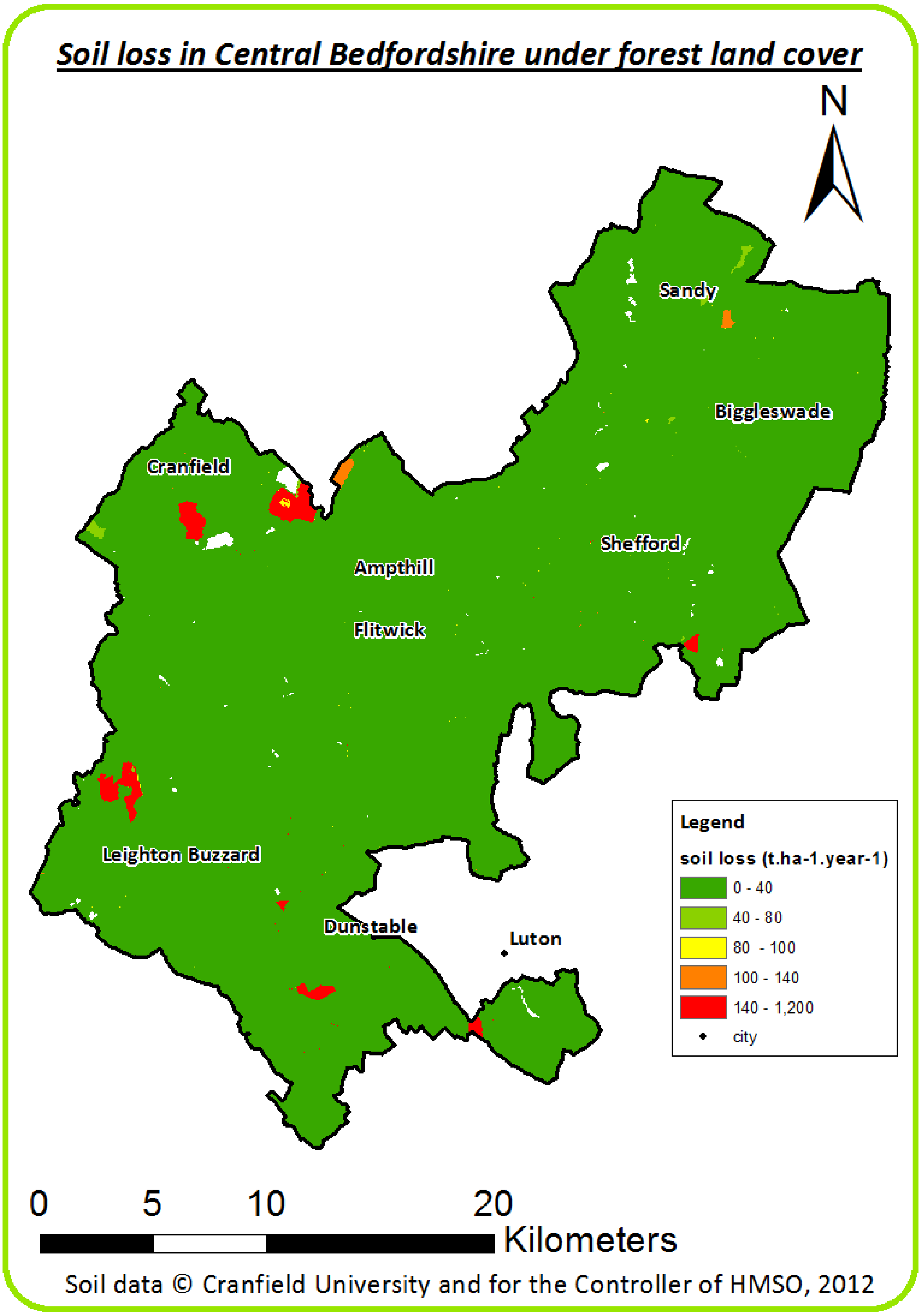

Figure C6. Predicted soil loss in Central Bedfordshire under woodland land use. Current urban areas stay as urban areas in this scenario.

3. Scenario 3: Pasture land use

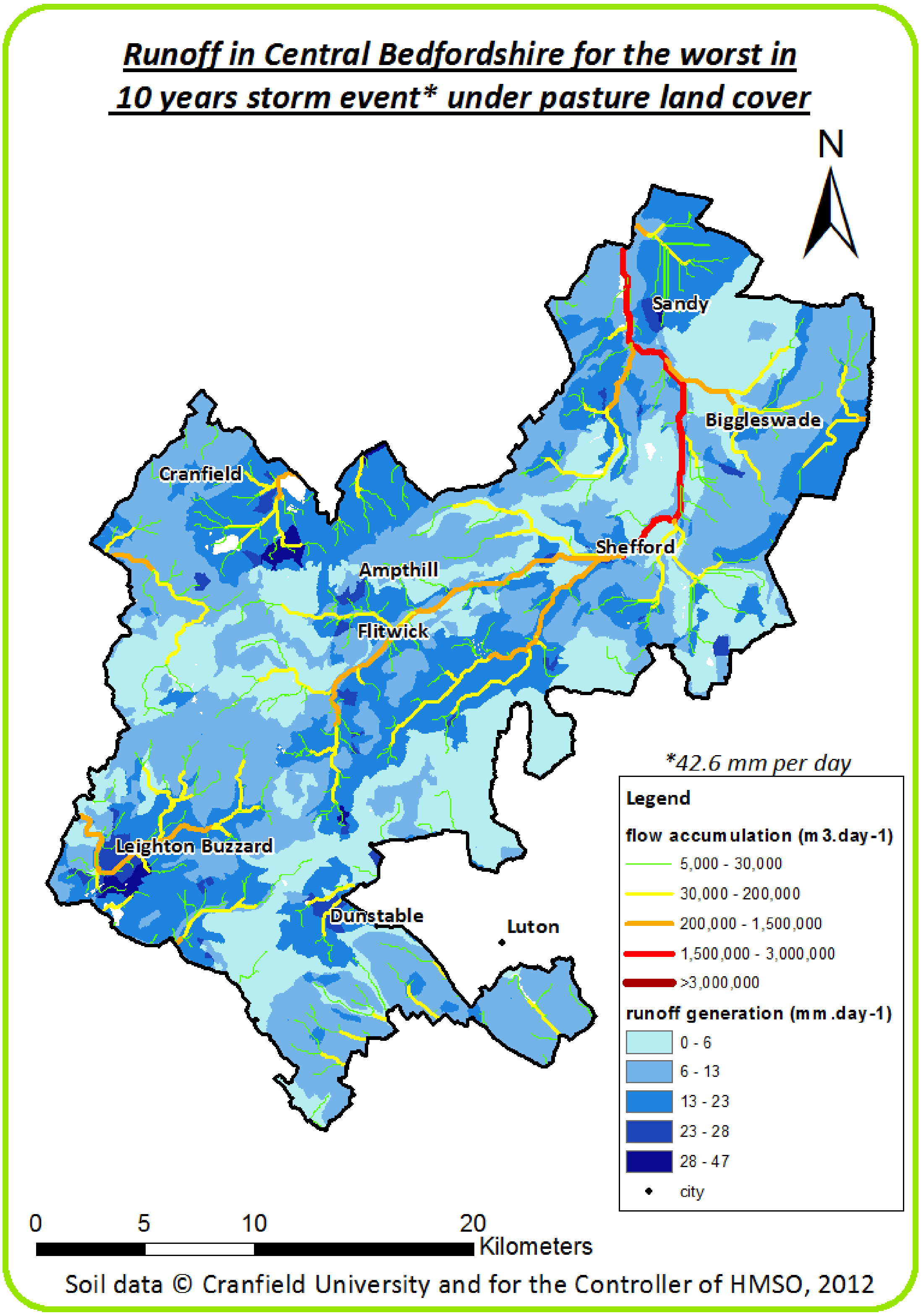

Figure C7. Predicted runoff in Central Bedfordshire for the 1 in 10 years storm event under pasture land use. Previous soil wetness was assumed to be intermediate. Current urban areas stay as urban areas in this scenario.

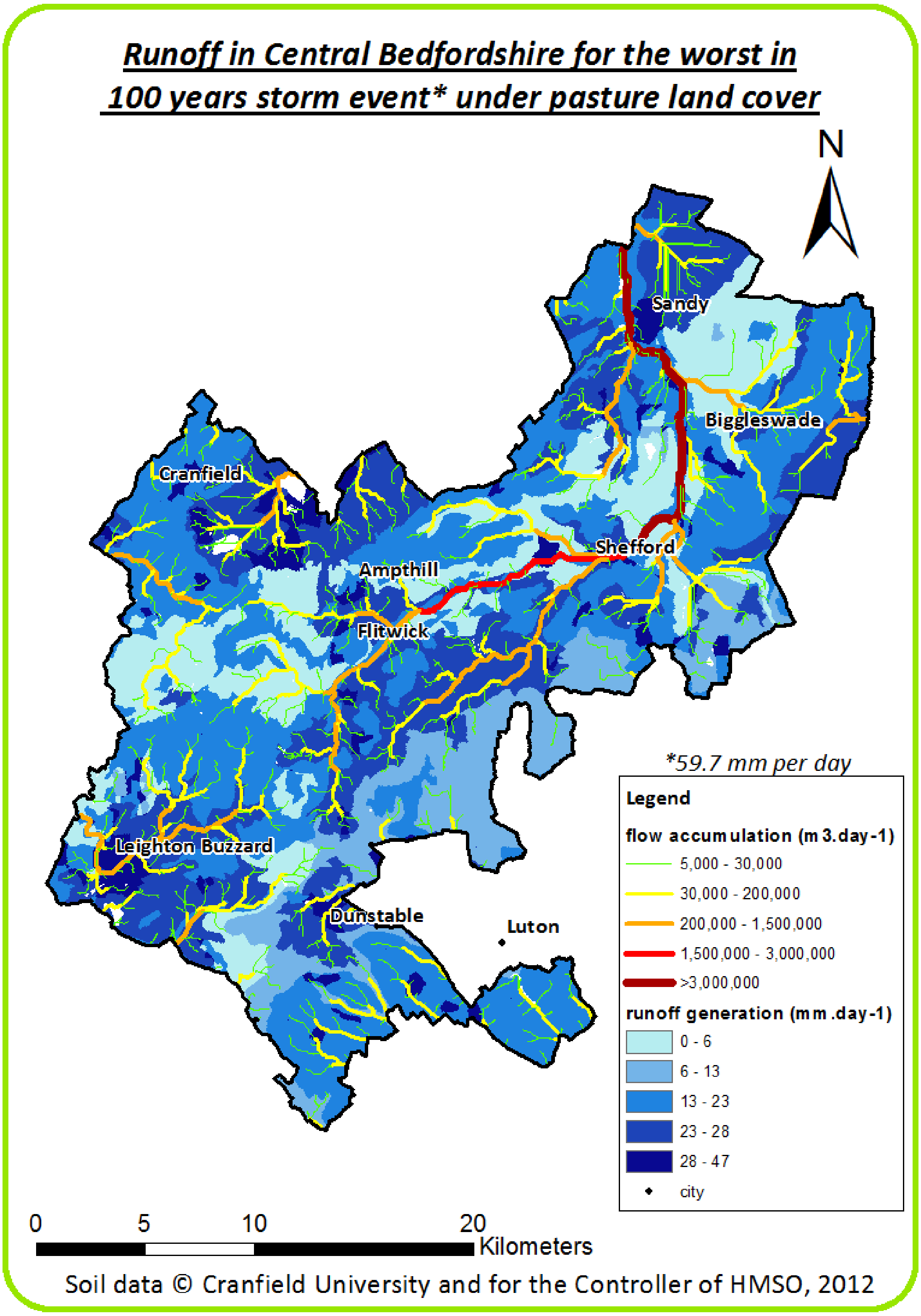

Figure C8. Predicted runoff in Central Bedfordshire for the 1 in 100 years storm event under pasture land use. Previous soil wetness was assumed to be intermediate. Current urban areas stay as urban areas in this scenario.

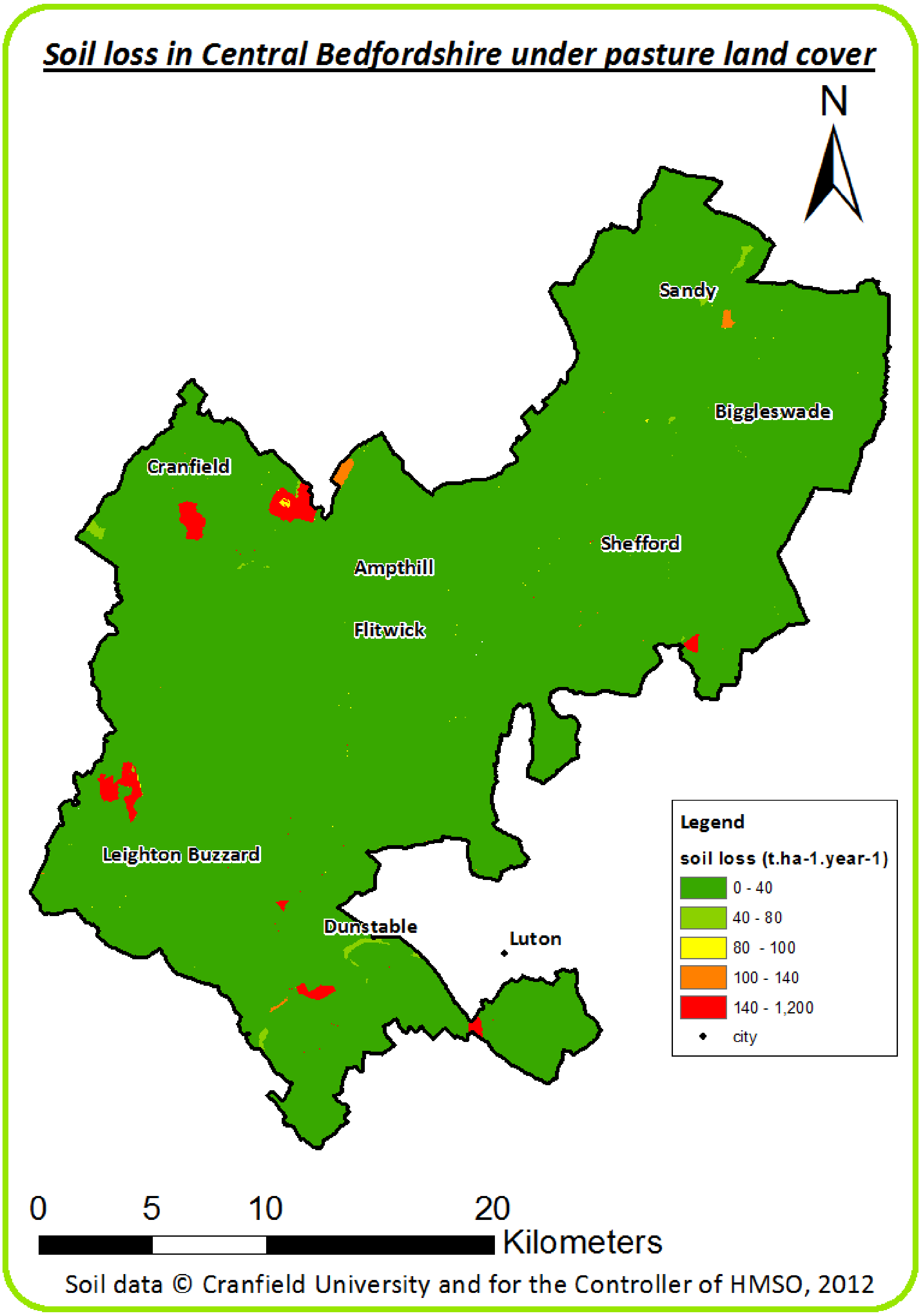

Figure C9. Predicted soil loss in Central Bedfordshire under pasture land use. Current urban areas stay as urban areas in this scenario.

4. Scenario 4: Implementation of the Biodiversity Action Plan (BAP)

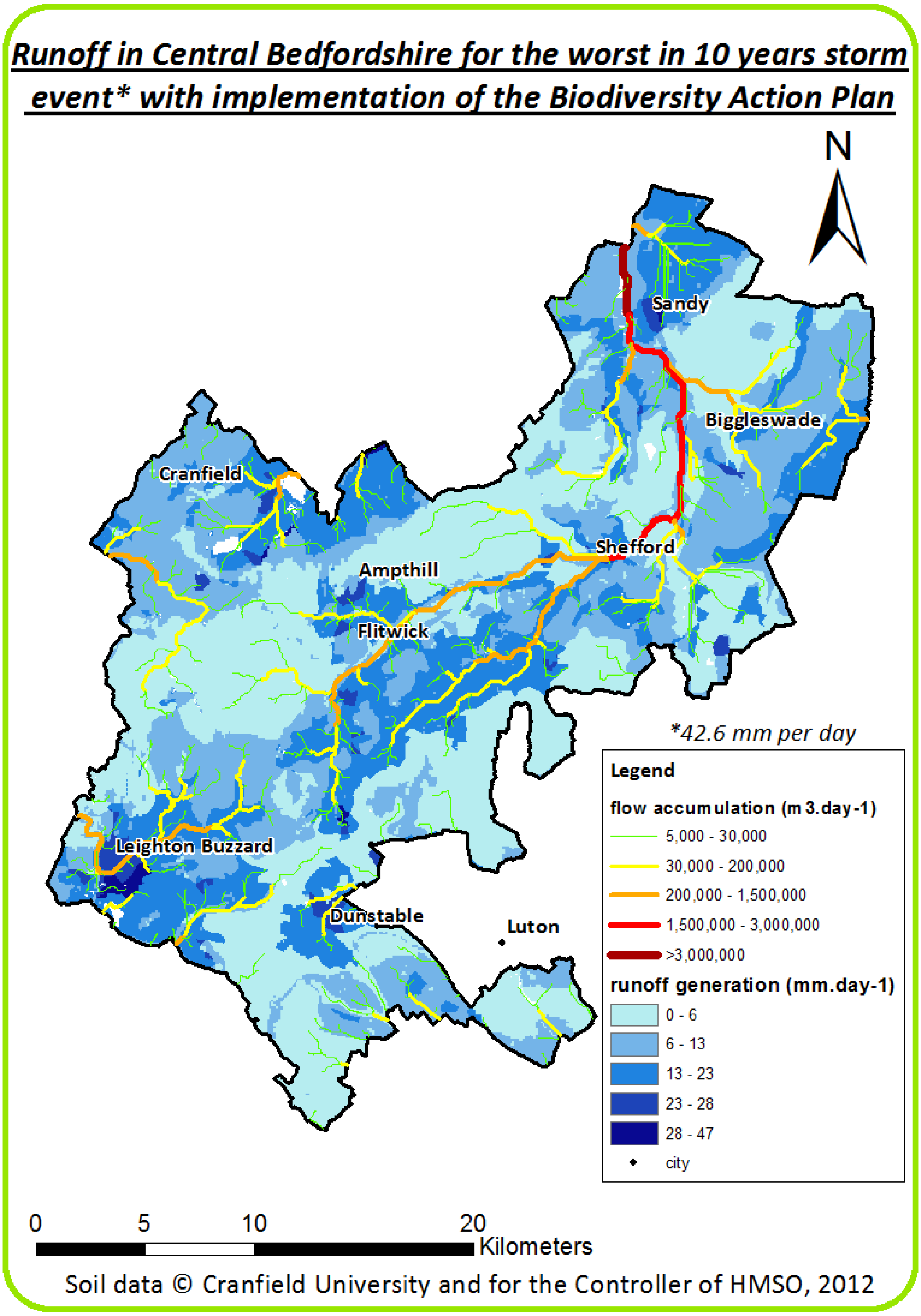

Figure C10. Predicted runoff in Central Bedfordshire for the 1 in 10 years storm event whit implementation of the BAP. Previous soil wetness was assumed to be intermediate.

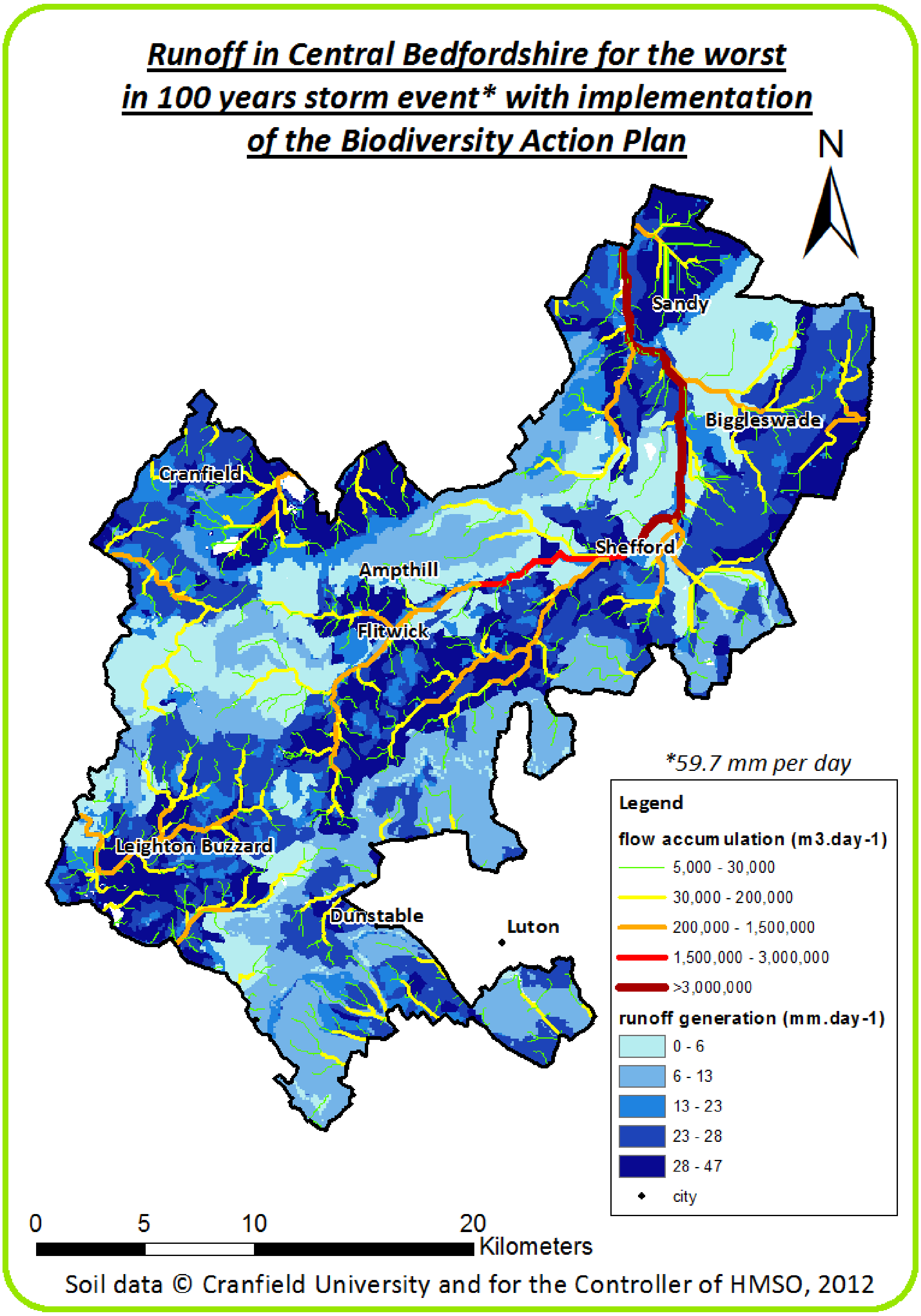

Figure C11. Predicted runoff in Central Bedfordshire for the 1 in 100 years storm event whit implementation of the BAP. Previous soil wetness was assumed to be intermediate.

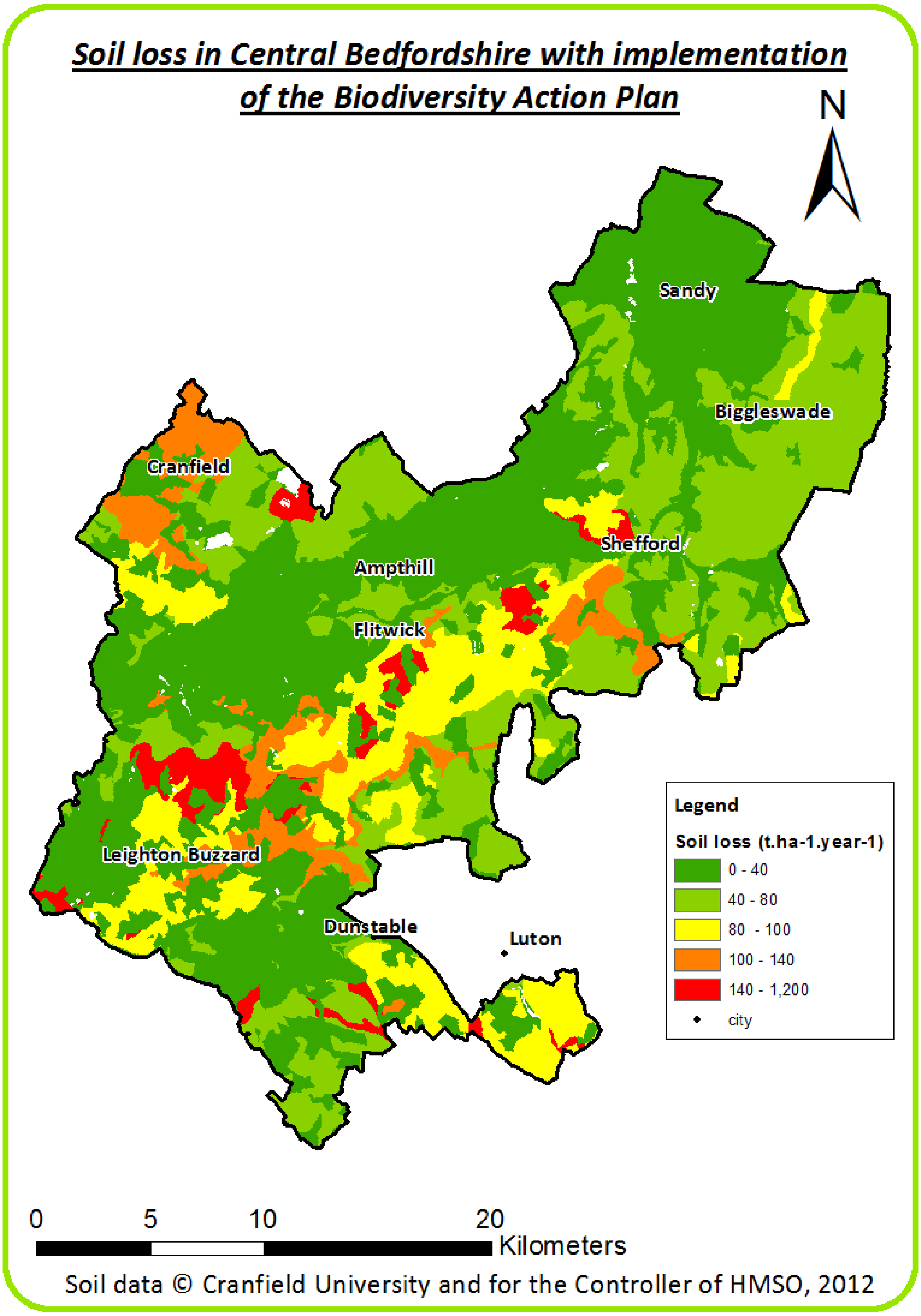

Figure C12. Predicted soil loss in Central Bedfordshire with implementation of the BAP.

5. Scenario 5: Implementation of good land management techniques

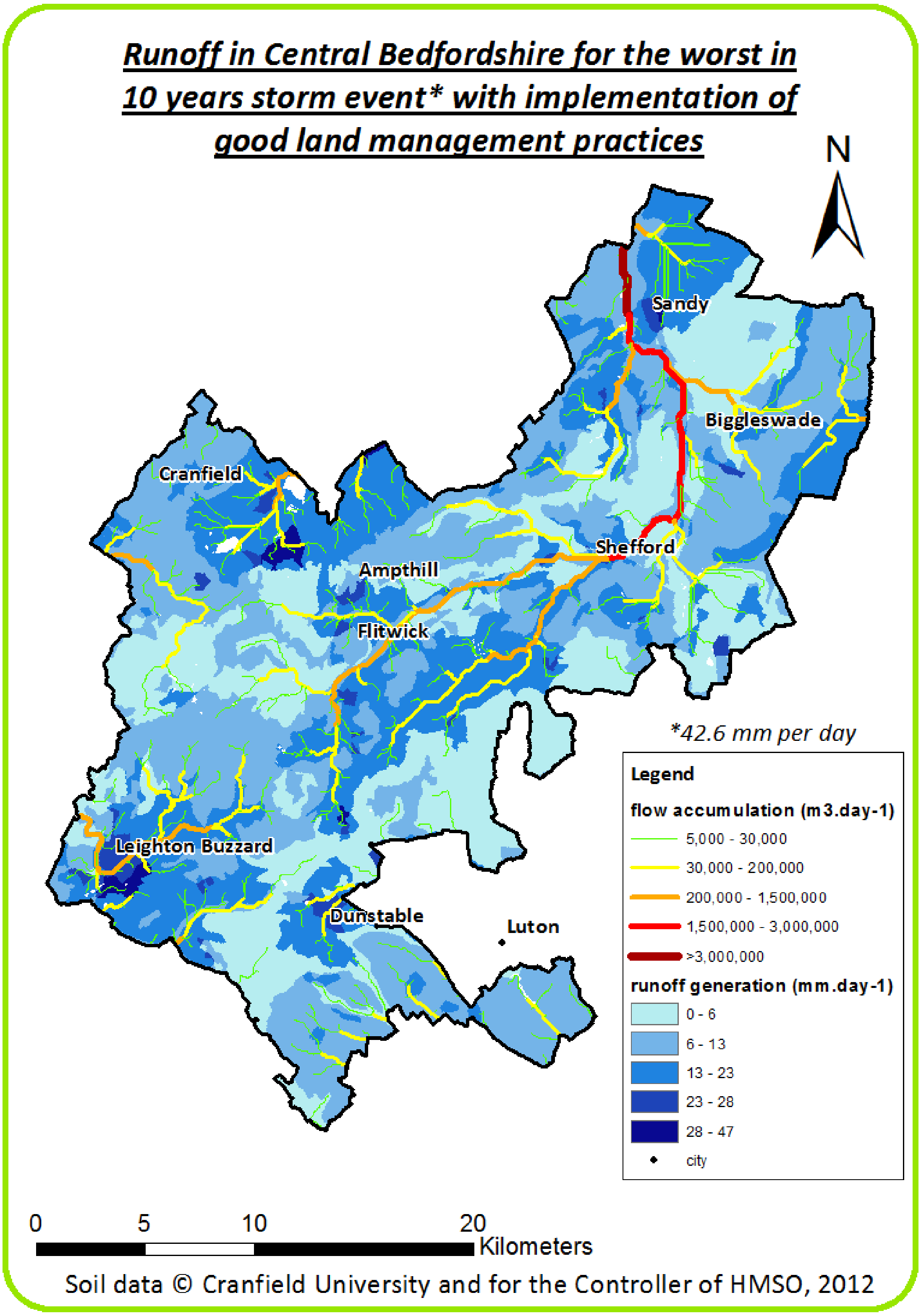

Figure C13. Predicted runoff in Central Bedfordshire for the 1 in 10 years storm event whit implementation of good land management techniques to prevent erosion and runoff in arable land. Such land management techniques are specified in the methodology of the scenario. Previous soil wetness was assumed to be intermediate.

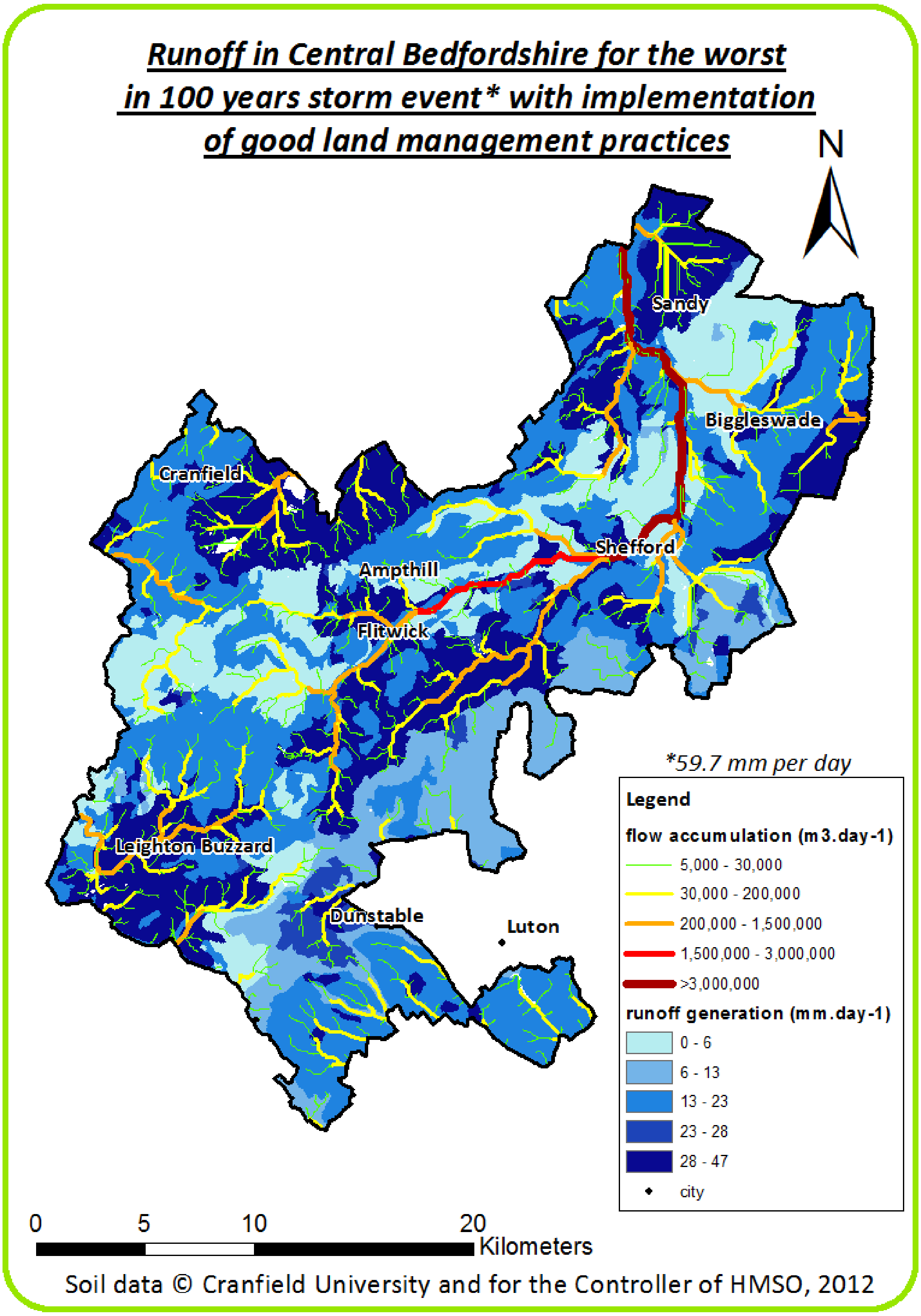

Figure C14. Predicted runoff in Central Bedfordshire for the 1 in 100 years storm event whit implementation of good land management techniques to prevent erosion and runoff in arable land. Such land management techniques are specified in the methodology of the scenario. Previous soil wetness was assumed to be intermediate.

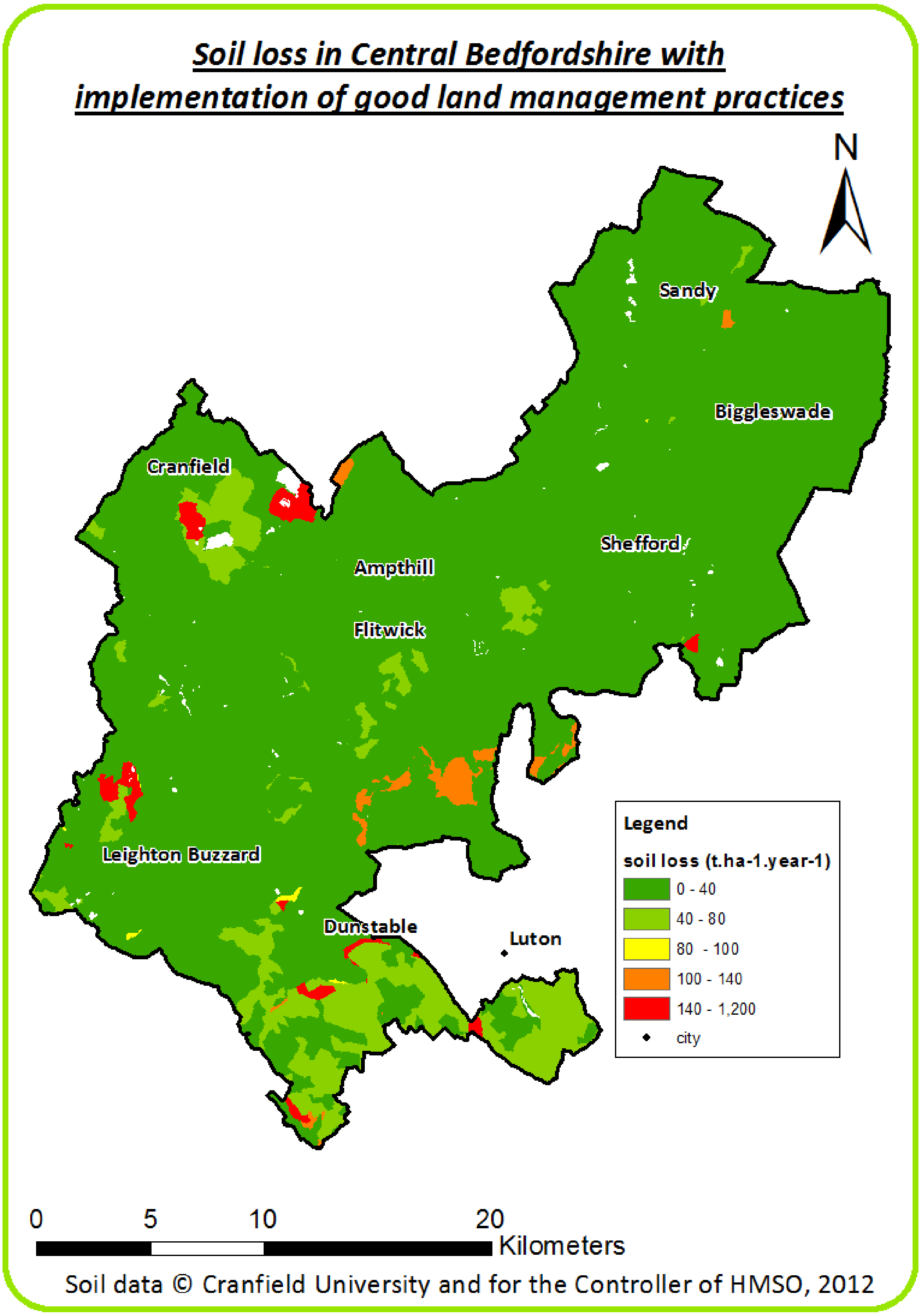

Figure C15. Predicted soil loss in Central Bedfordshire with implementation of the good land management techniques to prevent erosion and runoff in arable land. Such land management techniques are specified in the methodology of the scenario.

C2: Scenario Result tables

1. Scenario 1: Widespread urban development

Table C1. Mean runoff predicted (42.6 mm day^{-1}) after the 1 in 10 years rainfall event for urban development throughout the entire Central Bedfordshire. Values on the table are interpreted as follow: mean runoff estimated for each combination of land use and Hydrologic soil group (standard deviation – SD- for each combination of land use and soil type). Current proportion of the different urban land covers within Central Bedfordshire was assigned to the new urban development in order to estimate its behaviour against runoff.

	NEW URBAN DEVELOPMENT	CURRENT URBAN DEVELOPMENT			
Soil type	**Weighted urban area**	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**
A	5.4 (2.12)	7.3 (0.82)	4.3 (0.72)	19.5 (0.92)	0.2 (0.7)
B	12.7 (2.53)	14.4 (0.37)	11.4 (0.48)	24.2 (0.43)	3.1 (0.32)
C	17.9 (2.02)	20.9 (0.83)	16.8 (0.71)	27.8 (0.78)	9.2 (0.38)
D	22.6 (1.74)	24.1(0.84)	19.5 (0.15)	29.9 (0.48)	13.7 (1.14)

Table C2. Mean runoff predicted (59.7mm day^{-1}) after the 1 in 100 years rainfall event for urban development throughout the entire Central Bedfordshire. Values on the table are interpreted as follow: mean runoff estimated for each combination of land use and Hydrologic soil group (standard deviation – SD- for each combination of land use and soil type). Current proportion of the different urban land covers within Central Bedfordshire was assigned to the new urban development in order to estimate its behaviour against runoff.

	NEW URBAN DEVELOPMENT	CURRENT URBAN DEVELOPMENT			
Soil type	**Weighted urban area**	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**
A	13.1 (4)	16.5 (1.16)	11.5 (1.08)	33.7 (1.24)	0.6 (1.35)
B	24.4 (3.61)	26.9 (0.56)	22.6 (0.68)	39.4 (0.58)	9.4 (0.51)
C	31.5 (2.77)	35.4 (1.14)	30.0 (1.05)	43.8 (0.97)	19.3 (0.74)
D	37.5 (2.17)	39.4 (1.13)	33.6 (0.21)	46.1 (0.58)	25.9 (1.97)

Table C3. Mean erosion predicted (ton ha^{-1} $year^{-1}$) for urban development through the entire county. Values on the table are interpreted as follow: mean erosion for each combination of land use and soil type (standard deviation – SD- for each combination of land use and soil type). NA (Not Applicable) means that a certain combination of land use and soil type does not appear in the area. Current proportion of the different urban land covers within Central Bedfordshire was assigned to the new urban development in order to estimate its behaviour against erosion.

	NEW URBAN DEVELOPMENT	**CURRENT URBAN DEVELOPMENT**			
Soil type	**Weighted urban area**	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**
deep clay	33.5 (22.31)	1.0 (7.27)	150.3 (32.55)	1.0 (6.18)	8.5 (14.25)
deep loam	18.3 (6.27)	0.4 (2.52)	45.8 (1.61)	0.9 (5.11)	9.1 (15.11)
deep loam over gravel	13.6 (13.07)	0.4 (3.73)	27.9 (12.34)	0.7 (3.99)	2.8 (8.61)
deep loam to clay	47.6 (63.45)	1.7 (11.28)	639.0 (208.09)	0.9 (5.16)	13.4 (9.75)
deep sandy	41.6 (56.35)	0.9 (6.87)	252.8 (160.57)	1.6 (3.15)	10.0 (4.65)
deep silty to clay	NA	NA	NA	NA	NA
loam over chalk	20.1 (20.17)	0.2 (3.65)	2.2 (20.39)	0.3 (3.72)	1.8 (9.01)
loam over red sandstone	23.6 (13.07)	0.7 (5.32)	NA	0.8 (4.96)	5.7 (4.43)
seasonally wet deep clay	37.9 (57.12)	0.9 (6.93)	231.0 (116.96)	0.7 (4.34)	9.4 (3.44)
seasonally wet deep peat to loam	3.7 (2.13)	0.6 (1.67)	2.1 (1.55)	NA	0.7 (1.15)
seasonally wet loam over gravel	4.4 (1.56)	0.2 (1.4)	NA	NA	NA
shallow silty over chalk	54.9 (63.56)	1.6 (13.76)	325.5 (306.26)	0.7 (4.57)	18.3 (30.06)
silty over chalk	110.4 (175.08)	0.2 (0.57)	1115.2 (104.49)	NA	10.8 (42.05)

2. Scenario 2: Woodland land use

Table C4. Mean runoff predicted (mm day^{-1}) in Central Bedfordshire under woodland land use after the 1 in 10 years rainfall event. Current urban areas stay in the same place. Values on the table are interpreted as follow: mean runoff estimated for each combination of land use and Hydrologic soil group (standard deviation – SD- for each combination of land use and soil type).

	URBAN AREAS				NON-URBAN AREAS
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Woodland**
A	7.3 (0.82)	4.3 (0.72)	19.5 (0.92)	0.2 (0.7)	5.0 (0.01)
B	14.4 (0.37)	11.4 (0.48)	24.2 (0.43)	3.1 (0.32)	0.6 (0.02)
C	20.9 (0.83)	16.8 (0.71)	27.8 (0.78)	9.2 (0.38)	4.8 (0.02)
D	24.1 (0.84)	19.5 (0.15)	29.9 (0.48)	13 (1.64)	9.6 (0.02)

Table C5. Mean runoff predicted (mm d^{-1}) in Central Bedfordshire under woodland land use after the 1 in 100 years rainfall event and. Current urban areas stay in the same place. Values on the table are interpreted as follow: mean runoff estimated for each combination of land use and Hydrologic soil group (standard deviation – SD- for each combination of land use and soil type).

	URBAN AREAS				NON-URBAN AREAS
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Woodland**
A	16.5 (1.16)	11.5 (1.08)	33.7 (1.24)	0.6 (1.35)	1.8 (0.07)
B	26.9 (0.56)	22.6 (0.68)	39.4 (0.58)	9.4 (0.51)	0.1 (0.05)
C	35.4 (1.14)	30.0 (1.05)	43.8 (0.97)	19.3 (0.74)	12.4 (0.04)
D	39.4 (1.13)	33.6 (0.21)	46.1 (0.58)	24.9 (2.6)	20.0 (0.05)

Table 6. Mean erosion predicted (ton ha^{-1} year^{-1}) in Central Bedfordshire under woodland land use. Current urban areas stay in the same place. Values on the table are interpreted as follow: mean erosion for each combination of land use and soil type (standard deviation – SD- for each combination of land use and soil type). NA means that a certain combination of land use and soil type does not appear in the area.

	URBAN AREAS				NON-URBAN AREAS
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Woodland**
deep clay	1.0 (7.27)	150.3 (32.55)	1.0 (6.18)	8.5 (14.25)	0.3 (0.15)
deep loam	0.4 (2.52)	45.8 (1.61)	0.9 (5.11)	9.1 (15.11)	0.2 (0.04)
deep loam over gravel	0.4 (3.73)	27.9 (12.34)	0.7 (3.99)	2.8 (8.61)	0.1 (0.11)
deep loam to clay	1.7 (11.28)	639.0 (208.09)	0.9 (5.16)	13.4 (9.75)	0.4 (0.23)
deep sandy	0.9 (6.87)	252.8 (160.57)	1.6 (3.15)	10.0 (4.65)	0.4 (0.17)
deep silty to clay	NA	NA	NA	NA	0.3 (0.07)
loam over chalk	0.2 (3.65)	2.2 (20.39)	0.3 (3.72)	1.8 (9.01)	0.3 (0.11)
loam over red sandstone	0.7 (5.32)	NA	0.8 (4.96)	5.7 (4.43)	0.2 (0.09)
seasonally wet deep clay	0.9 (6.93)	231.0 (116.96)	0.7 (4.34)	9.4 (3.44)	0.3 (0.21)
seasonally wet deep peat to loam	0.6 (1.67)	2.1 (1.55)	NA	0.7 (1.15)	NA
seasonally wet loam over gravel	0.2 (1.4)	NA	NA	NA	NA
shallow silty over chalk	1.6 (13.76)	325.5 (306.26)	0.7 (4.57)	18.3 (30.06)	0.5 (0.43)
silty over chalk	0.2 (0.57)	1115.2 (104.49)	NA	10.8 (42.05)	NA

3. Scenario 3: Pasture land use

Table C7. Mean runoff predicted (mm day^{-1}) in Central Bedfordshire under pasture land use after the 1 in 10 years rainfall event. Current urban areas stay in the same place. Values on the table are interpreted as follow: mean runoff estimated for each combination of land use and Hydrologic soil group (standard deviation – SD- for each combination of land use and soil type(See Table A.4).

	URBAN AREAS				NON-URBAN AREAS
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Pasture**
A	7.3 (0.82)	4.3 (0.72)	19.5 (0.92)	0.2 (0.7)	0.2 (0.1)
B	14.4 (0.37)	11.4 (0.48)	24.2 (0.43)	3.1 (0.32)	1.5 (0.15)
C	20.9 (0.83)	16.8 (0.71)	27.8 (0.78)	9.2 (0.38)	11.3 (0.08)
D	24.1 (0.84)	19.5 (0.15)	29.9 (0.48)	13.7 (1.14)	15.2 (0.08)

Table C8. Mean runoff predicted (mm day^{-1}) in Central Bedfordshire under pasture land use after the 1 in 100 years rainfall event. Current urban areas stay in the same place. Values on the table are interpreted as follow: mean runoff estimated for each combination of land use and Hydrologic soil group (standard deviation – SD- for each combination of land use and soil type).

	URBAN AREAS				NON-URBAN AREAS
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Pasture**
A	16.5 (1.16)	11.5 (1.08)	33.7 (1.24)	0.6 (1.35)	2.7 (0.19)
B	26.9 (0.56)	22.6 (0.68)	39.4 (0.58)	9.4 (0.51)	6.2 (0.25)
C	35.4 (1.14)	30.0 (1.05)	43.8 (0.97)	19.3 (0.74)	22.4 (0.11)
D	39.4 (1.13)	33.6 (0.21)	46.1 (0.58)	25.9 (1.97)	28.0 (0.12)

Table C9. Mean erosion predicted (ton ha^{-1} year^{-1}) in Central Bedfordshire under pasture land use. Current urban areas stay at the same place. Values on the table are interpreted as follow: mean erosion for each combination of land use and soil type (standard deviation – SD- for each combination of land use and soil type). 0 means that a certain combination of land use and soil type does not appear in the area.

	URBAN AREAS				NON-URBAN AREAS
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Pasture**
deep clay	1.0 (7.27)	150.3 (32.55)	1.0 (6.18)	8.5 (14.25)	7.4 (3.4)
deep loam	0.4 (2.52)	45.8 (1.61)	0.9 (5.11)	9.1 (15.11)	4.0 (1.04)
deep loam over gravel	0.4 (3.73)	27.9 (12.34)	0.7 (3.99)	2.8 (8.61)	3.3 (2.68)
deep loam to clay	1.7 (11.28)	639.0 (208.09)	0.9 (5.16)	13.4 (9.75)	9.7 (5.69)
deep sandy	0.9 (6.87)	252.8 (160.57)	1.6 (3.15)	10.0 (4.65)	9.3 (4.18)
deep silty to clay	NA	NA	NA	NA	6.8 (2.18)
loam over chalk	0.2 (3.65)	2.2 (20.39)	0.3 (3.72)	1.8 (9.01)	7.4 (2.9)
loam over red sandstone	0.7 (5.32)	NA	0.8 (4.96)	5.7 (4.43)	5.8 (2.23)
seasonally wet deep clay	0.9 (6.93)	231.0 (116.96)	0.7 (4.34)	9.4 (3.44)	6.5 (5.2)
seasonally wet deep peat to loam	0.6 (1.67)	2.1 (1.55)	NA	0.7 (1.15)	0.8 (0.44)
seasonally wet loam over gravel	0.2 (1.4)	NA	NA	NA	NA
shallow silty over chalk	1.6 (13.76)	325.5 (306.26)	0.7 (4.57)	18.3 (30.06)	12.7 (10.65)
silty over chalk	0.2 (0.57)	1115.2 (104.49)	NA	10.8 (42.05)	18.0 (6.46)

4. Scenario 4: Biodiversity Action Plan (BAP)

Table C10. Mean runoff predicted (mm day^{-1}) in Central Bedfordshire under implementation of the BAP use after the 1 in 10 years rainfall event. Values on the table are interpreted as follow: mean runoff estimated for each combination of land use and Hydrologic soil group (standard deviation – SD- for each combination of land use and soil type).

	URBAN AREAS				NON-URBAN AREAS		
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Pasture**	**Arable land**	**Woodland**
A	7.1 (1.48)	4.1 (1.26)	18.25 (4.48)	0.4 (1.23)	0.7 (1.88)	1.5 (1.04)	4.5 (1.15)
B	14.2 (1.84)	11.0 (1.98)	23.8 (2.82)	3.0 (1.12)	1.8 (1.72)	4.0 (0.75)	1.4 (2.47)
C	20.6 (1.94)	15.8 (3.26)	27.4 (3.02)	9.1 (0.92)	11.1 (1.85)	12.6 (1.02)	5.4 (1.56)
D	23.9 (1.85)	18.9 (2.19)	29.3 (3.24)	13.6 (1.12)	15.0 (1.7)	16.9 (0.98)	10.1 (2.46)

Table C11. Mean runoff predicted (mm day^{-1}) in Central Bedfordshire with implementation of the BAP use after the 1 in 100 years rainfall event. Values on the table are interpreted as follow: mean runoff estimated for each combination of land use and Hydrologic soil group (standard deviation – SD- for each combination of land use and soil type).

	URBAN AREAS				NON-URBAN AREAS		
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Pasture**	**Arable land**	**Woodland**
A	15.9 (3.03)	10.6 (3)	31.0 (8.73)	0.8 (1.65)	3.2 (3.02)	5.8 (1.71)	2.1 (2.53)
B	26.5 (2.98)	22.0 (3.59)	38.9 (4.58)	8.9 (2.31)	6.5 (3.08)	11.0 (1.44)	2.8 (5.36)
C	35.0 (2.71)	28.6 (5.03)	43.2 (4.09)	19.3 (1.47)	22.2 (3)	24.3 (1.59)	13.2 (2.7)
D	39.0 (2.49)	32.9 (3.01)	45.4 (4.13)	25.7 (1.7)	27.8 (2.64)	30.2 (1.41)	20.6 (3.81)

Table C12. Mean erosion predicted (ton ha^{-1} year^{-1}) in Central Bedfordshire with implementation of the BAP. Values on the table are interpreted as follow: mean erosion for each combination of land use and soil type (standard deviation – SD- for each combination of land use and soil type). 0 means that a certain combination of land use and soil type does not appear in the area.

	URBAN AREAS				NON-URBAN AREAS		
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Pasture**	**Arable land**	**Woodland**
deep clay	1.0 (7.06)	150.0 (33.33)	1.1 (6.9)	3.7 (7.91)	9.4 (11.4)	6.9 (2.18)	9.6 (13.5)
deep loam	0.4 (2.41)	45.8 (2.2)	0.9 (4.85)	9.8 (14.37)	3.3 (1.41)	4.0 (0.93)	5.1 (3.16)
deep loam over gravel	0.4 (3.62)	28.1 (12.51)	0.6 (3.33)	2.8 (8.53)	5.3 (4.6)	2.9 (2.13)	2.8 (2.17)
deep loam to clay	1.7 (10.41)	398.1 (69.33)	0.9 (5.21)	11.8 (8.82)	34.7 (143.39)	9.5 (3.77)	12.1 (28.02)
deep sandy	0.9 (7.16)	220.9 (135.45)	6.1 (24.64)	9.4 (4.23)	22.5 (72.7)	6.9 (3.3)	15.6 (37.11)
deep silty to clay	NA	NA	NA	NA	6.6 (3.07)	7.0 (0.05)	5.6 (0.55)
loam over chalk	0.2 (3.16)	1.0	0.3 (3.8)	1.5 (7.57)	6.6 (6.82)	7.3 (2.26)	6.0 (5.88)
loam over red sandstone	0.6 (4.19)	NA	0.7 (4.19)	3.6 (4.68)	4.3 (2.4)	5.4 (1.52)	6.0 (2.95)
seasonally wet deep clay	0.9 (6.46)	122.7 (136.16)	0.5 (5.03)	1.3 (2.84)	4.5 (27.26)	5.9 (4.59)	33.8 (79.59)
seasonally wet deep peat to loam	0.7 (1.9)	2.1 (1.58)	NA	0.7 (1.15)	0.9 (0.45)	0.8 (0.34)	0.9 (0.85)
seasonally wet loam over gravel	0.2 (1.31)	NA	NA	NA	NA	1.0 (0.3)	NA
shallow silty over chalk	1.3 (8.97)	150.7 (13.85)	0.7 (4.58)	7.8 (6.52)	26.7 (66.06)	7.4 (5.46)	33.3 (83.4)
silty over chalk	0.2 (0.54)	NA	NA	10.9 (42.05)	87.3 (269.52)	16.1 (2.10)	NA

5. Scenario 5: Implementation of management techniques in arable land

Table C13. Mean runoff predicted (mm day^{-1}) in Central Bedfordshire with implementation of some good land management practices, specified in the methodology, after the 1 in 10 years rainfall event. Values on the table are interpreted as follow: mean runoff estimated for each combination of land use and Hydrologic soil group (standard deviation – SD- for each combination of land use and soil type).

	URBAN AREAS				NON-URBAN AREAS		
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Pasture**	**Arable land**	**Woodland**
A	7.3 (0.97)	4.3 (0.85)	19.5 (1.31)	0.2 (0.79)	0.3 (0.99)	0.8 (0.94)	4.6 (0.3)
B	14.4 (0.76)	11.3 (0.75)	24.1 (1.33)	3.2 (0.5)	1.6 (0.65)	1.9 (0.74)	0.6 (0.23)
C	20.8 (1.13)	16.7 (0.86)	27.8 (1.26)	9.2 (0.46)	11.2 (0.7)	11.5 (0.57)	5.1 (0.5)
D	24.1 (1.05)	19.5 (0.26)	29.9 (0.77)	13.5 (1.08)	15.2 (0.64)	15.6 (0.63)	9.6 (0.7)

Table C14. Mean runoff predicted (mm day^{-1}) in Central Bedfordshire with implementation of some good land management practices, specified in the methodology, after the 1 in 100 years rainfall event. Values on the table are interpreted as follow: mean runoff estimated for each combination of land use and Hydrologic soil group (standard deviation – SD- for each combination of land use and soil type).

	URBAN AREAS				NON-URBAN AREAS		
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Pasture**	**Arable land**	**Woodland**
A	16.5 (1.46)	11.5 (1.34)	33.6 (1.88)	0.6 (1.48)	2.8 (1.75)	4.4 (1.58)	1.6 (0.64)
B	26.9 (1.18)	22.6 (1.16)	39.3 (1.9)	9.4 (0.78)	6.3 (1.08)	7.0 (1.19)	0.2 (0.87)
C	35.3 (1.55)	30.0 (1.26)	43.7 (1.6)	19.3 (0.87)	22.4 (1.19)	22.7 (0.94)	12.9 (0.88)
D	39.3 (1.39)	33.6 (0.35)	46.1 (0.94)	25.6 (1.97)	28.0 (1.01)	28.5 (1)	20.0 (1.17)

Table C15. Mean erosion predicted (ton ha^{-1} $year^{-1}$) in Central Bedfordshire with implementation of some good land management practices, specified in the methodology. Values on the table are interpreted as follow: mean erosion for each combination of land use and soil type (standard deviation – SD- for each combination of land use and soil type). 0 means that a certain combination of land use and soil type does not appear in the area.

	URBAN AREAS				NON-URBAN AREAS		
Soil type	**Residential areas**	**Impervious**	**Industrial or commercial**	**Open spaces**	**Pasture**	**Arable land**	**Woodland**
deep clay	0.3 (1.62)	150.4 (32.92)	0.4 (3.03)	7.5 (11.52)	10.2 (6.85)	24.0 (7.9)	0.4 (2.17)
deep loam	0.1 (0.53)	46.2 (0.81)	0.3 (1.56)	4.7 (4.78)	3.4 (1.53)	12.3 (3)	0.4 (2.08)
deep loam over gravel	0.1 (0.82)	27.5 (12.26)	NA	2.1 (0.89)	5.5 (4.54)	9.5 (8.29)	0.1 (1.04)
deep loam to clay	0.4 (2.34)	643.7 (214.38)	0.4 (1.62)	12.6 (3.05)	8.0 (11.79)	36.6 (15.94)	0.6 (2.96)
deep sandy	0.4 (1.46)	253.9 (160.47)	1.6 (2.13)	9.8 (3.88)	11.5 (5.43)	26.7 (7.48)	0.8 (7.17)
deep silty to clay	NA	NA	NA	NA	5.5 (1.7)	21.9 (2.44)	0.3 (0)
loam over chalk	NA	0.6 (15.48)	0.1 (1.02)	0.1 (2.53)	3.9 (4.43)	29.2 (12.5)	0.8 (5.95)
loam over red sandstone	0.3 (1.29)	NA	0.2 (0.88)	5.4 (2.33)	3.4 (2.86)	21.6 (8.12)	0.4 (1.5)
seasonally wet deep clay	0.3 (1.96)	232.0 (118.63)	0.4 (1.58)	9.3 (2.94)	3.8 (6.81)	25.5 (17.62)	0.6 (5.23)
seasonally wet deep peat to loam	NA)	2.0 (0.73)	NA	0.5 (0.62)	0.9 (0.3)	2.3 (0.82)	0.1 (0.24)
seasonally wet loam over gravel	NA	NA	NA	NA	NA	2.9 (1.24)	NA
shallow silty over chalk	0.4 (4.77)	329.3 (309.97)	0.3 (0.63)	16.5 (28.41)	23.9 (14.35)	46.6 (51.87)	1.7 (5.74)
silty over chalk	0.2 (0.71)	1100.2 (150.99)	NA	5.4 (15.89)	18.9 (9.95)	75.2 (25.50)	NA

Appendix D: Additional Water Quality Results

Table D1 River Quality-Nitrates (EA, 2012)

River	Location	Grade (1-6; very low-very high)	Absolute value (mg/l)
River Great Ouse	North of Sandy	5	31.2
River Ivel	North of Sandy	6	41.7
River Ivel	Sandy	6	43.7
River Ivel	South of Sandy	6	62.1
Henlow Brook	East of Shefford	4	24.9
River Ivel	East of Shefford	6	44.6
River Ivel	Southeast of Shefford	6	41.8
River Hiz	Southeast of Shefford	6	75.2
River Flit	Shefford	5	31.5
River Flit	Between Flitwick and Shefford	6	57.1
River Flit	East of Shefford	6	71.5
River Lee	Southeast of Luton	6	66.7
Ouzel Brook	Between Leighton Buzzard and Dunstable	6	48.7
River Ouzel	Between Leighton Buzzard and Dunstable	6	45.2

Table D2 River Quality-Phosphates (EA, 2012)

River	Location	Grade (1-6; very low-very high)	Absolute value (mg/l)
River Great Ouse	North of Sandy	5	0.2
River Ivel	North of Sandy	5	0.2
River Ivel	Sandy	5	0.2
River Ivel	South of Sandy	6	1.7
Henlow Brook	East of Shefford	5	1.0
River Ivel	East of Shefford	4	0.2
River Ivel	Southeast of Shefford	2	0.1
River Hiz	Southeast of Shefford	5	0.5
River Flit	Shefford	5	0.5
River Flit	Between Flitwick and Shefford	5	0.3
River Flit	East of Shefford	5	0.4
River Lee	Southeast of Luton	5	0.4
Ouzel Brook	Between Leighton Buzzard and Dunstable	5	0.4
River Ouzel	Between Leighton Buzzard and Dunstable	5	0.3

Table D3 River Status (Phosphate status; a component of physico-chemical status) (EA, 2012)

River	Location	Phosphate status (to do)
River Great Ouse	North of Sandy	Bad/Poor
River Ivel	North of Sandy	Bad/Poor
River Ivel	South of Sandy	Bad/Poor
River Ivel Tributary	West of Sandy and Biggleswade	Good
Millbridge-Common Brooks	Between Sandy and Biggleswade	Bad
River Ivel	Biggleswade	Bad/Poor
River Ivel	South of Biggleswade	Bad/Poor
River Ivel	East of Shefford	Bad/Poor
River Ivel	Southeast of Shefford	Bad/Poor
River Hiz	Southeast of Shefford	Moderate - High
Henlow Brook	East of Shefford	Bad/Poor
River Flit	East of Shefford	Bad/Poor
River Flit	Shefford	Bad/Poor
River Flit	West of Shefford	Bad/Poor
Chicksands Brook	Northwest of Shefford	Good
Campton Brook	Southwest of Shefford	Bad/Poor
Campton Brook	Southwest of Shefford (close to A6)	Bad/Poor
Barton Brook	Southwest of Shefford	Bad/Poor
Running Waters-Steppingly	Between Ampthill and Flitwick	Bad/Poor
River Flit	Flitwick	Bad/Poor
River Flit	West of Flitwick (near M1)	Good
River Flit	Crossing M1 (East of Leighton Buzzard)	Bad/Poor
Broughton Brook	East of Milton Keynes	Good
Clipstone Brook	Between Leighton Buzzard and Dunstable	Good - Bad
River Ouzel or Lovat	West of Leighton Buzzard	Moderate
River Ouzel or Lovat	West of Dunstable	Moderate - Good
River Lee	Southwest of Dunstable	Good

Table D4 River Status (Specific Pollutant Quality) (EA, 2012)

River	Location	Specific Pollutant Quality
River Great Ouse	North of Sandy	High
River Ivel	North of Sandy	High
River Ivel	South of Sandy	High
River Ivel Tributary	West of Sandy and Biggleswade	High
Millbridge-Common Brooks	Between Sandy and Biggleswade	Moderate
River Ivel	Biggleswade	High
River Ivel	South of Biggleswade	High
River Ivel	East of Shefford	High
River Ivel	Southeast of Shefford	High
River Hiz	Southeast of Shefford	High
Henlow Brook	East of Shefford	Good
River Flit	East of Shefford	Good
River Flit	Shefford	Good
River Flit	West of Shefford	Good
Chicksands Brook	Northwest of Shefford	Good
Campton Brook	Southwest of Shefford	High
Campton Brook	Southwest of Shefford (close to A6)	Good
Barton Brook	Southwest of Shefford	Good
Running Waters-Steppingly	Between Ampthill and Flitwick	Moderate
River Flit	Flitwick	Good
River Flit	West of Flitwick (near M1)	Good
River Flit	Crossing M1 (East of Leighton Buzzard)	High
Broughton Brook	East of Milton Keynes	Good
Clipstone Brook	Between Leighton Buzzard and Dunstable	High
River Ouzel or Lovat	West of Leighton Buzzard	High
River Ouzel or Lovat	West of Dunstable	High
River Lee	Southwest of Dunstable	Moderate

Appendix E: Scenario Case Studies

In order to illustrate the future scenarios at a more local level, three case studies were carried out to provide snapshots of the effects of urban development, land management and the BAP on carbon storage, runoff, soil erosion and pollution risk. The three case study areas are an area of urban development north of Luton, a woodland near Biggleswade, and a farm between Ampthill and Shefford.

E1: North of Luton SSSA: Future urban development scenario

E1.1: Introduction

The population of Luton and southern Central Bedfordshire is predicted to grow substantially in the coming decades, creating a need to provide new housing locally. Population forecasts suggest that around 23,000 new homes will be needed by 2026 (LSBJTU 2010b). Therefore, a number of sites have been chosen around Luton and Central Bedfordshire to locate these new urban developments, which are referred to as Strategic Site Specific Allocations (SSSAs). One such site is the North of Luton SSSA, which will provide approximately 1,800 homes. Provision has also been made for an extra 2,200 homes if needed in the future (LSBJTU 2010a).

The North of Luton SSSA will be located as shown in the map (figure E1a). The location is favourable for new, large-scale development as it is relatively unconstrained, and in close proximity to existing facilities and public transport. The urban area forms the southern boundary, the A6 and M1 form the eastern and western boundaries, and the Chilterns Area of Outstanding Natural Beauty forms the northern boundary. The Green Belt boundary will be altered, with the area to be developed upon removed, and the Green Belt boundary shifted. The site is located mostly on arable land, with a few small patches of woodland vegetation (EIONET 2006). The site is soil is mostly deep loam to clay and loam over chalk, the Ashley and Swaffham Prior series, respectively (NSRI 2008a, b, c & 2009; see figure E1b).

To provide new economic activity in the area, there will also be 20 hectares of new employment land, concentrated to the western and eastern ends of the SSSA to benefit from good transport links. New local centres will provide community facilities and new supermarkets to provide for everyday needs. New green infrastructure will be provided, linking existing and new landscape, ecology and archaeological features, creating multifunctional green corridors. The SSSA will primarily be accessed by existing roads, but will also benefit from access on to the Luton Northern Bypass in the future. The SSSA will be divided into areas linked principally by a spine road, with land uses generating significant volumes of travel located along the spine road to encourage public transport use (LSBJTU 2010a).

A drainage strategy will be devised to mitigate the risk of surface water flooding and further surface water flooding in the urban area; “this will be prepared jointly by the Joint Committee, the developers and the Environment Agency and will take into account advice provided in the Water Cycle Study and Strategic Flood Risk Assessment relating to flood risk, flood resistance and mitigation measures” (LSBJTU 2010a).

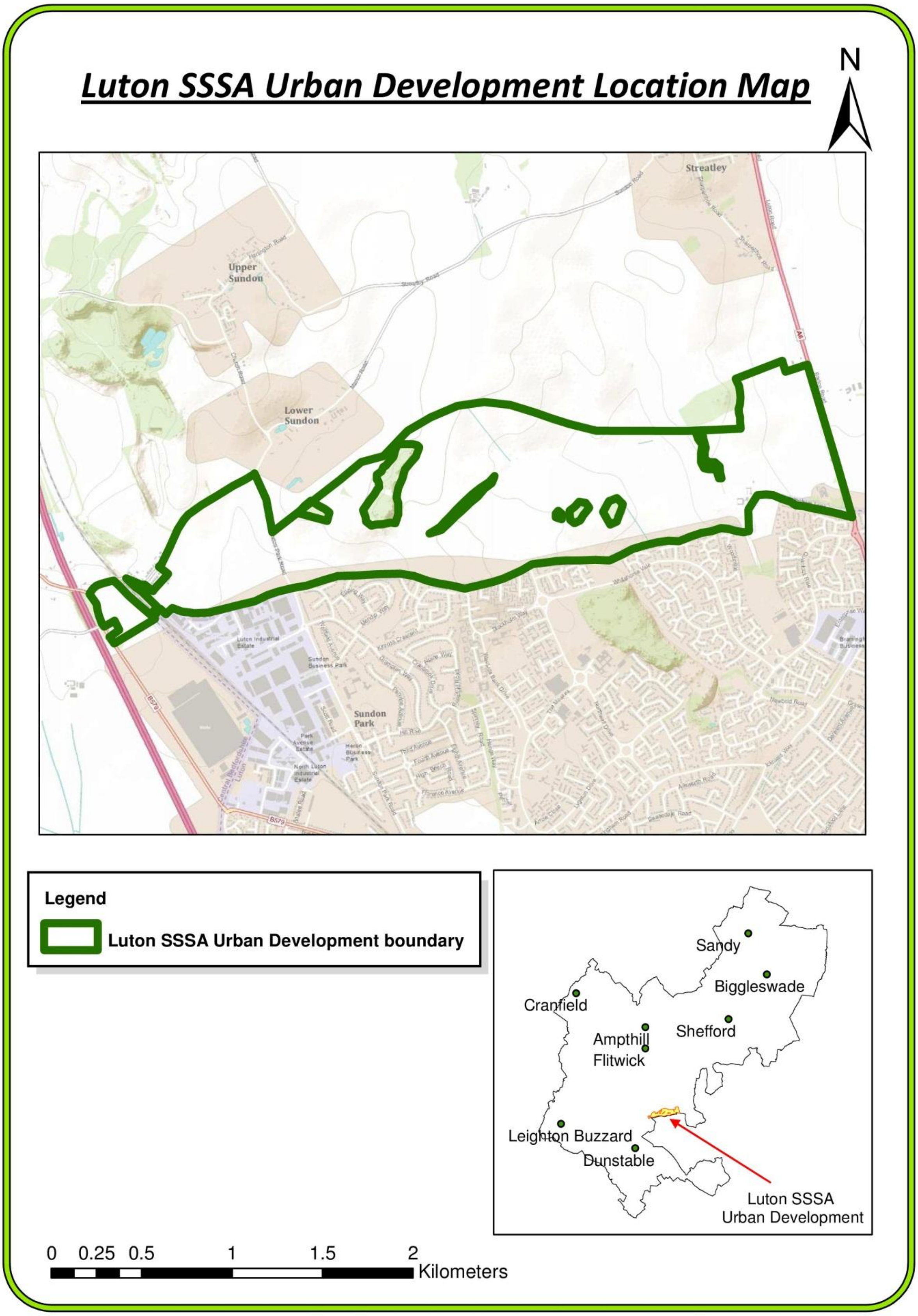

Figure E1a The location of Luton SSSA (Digitised from LSBJTU 2010a).

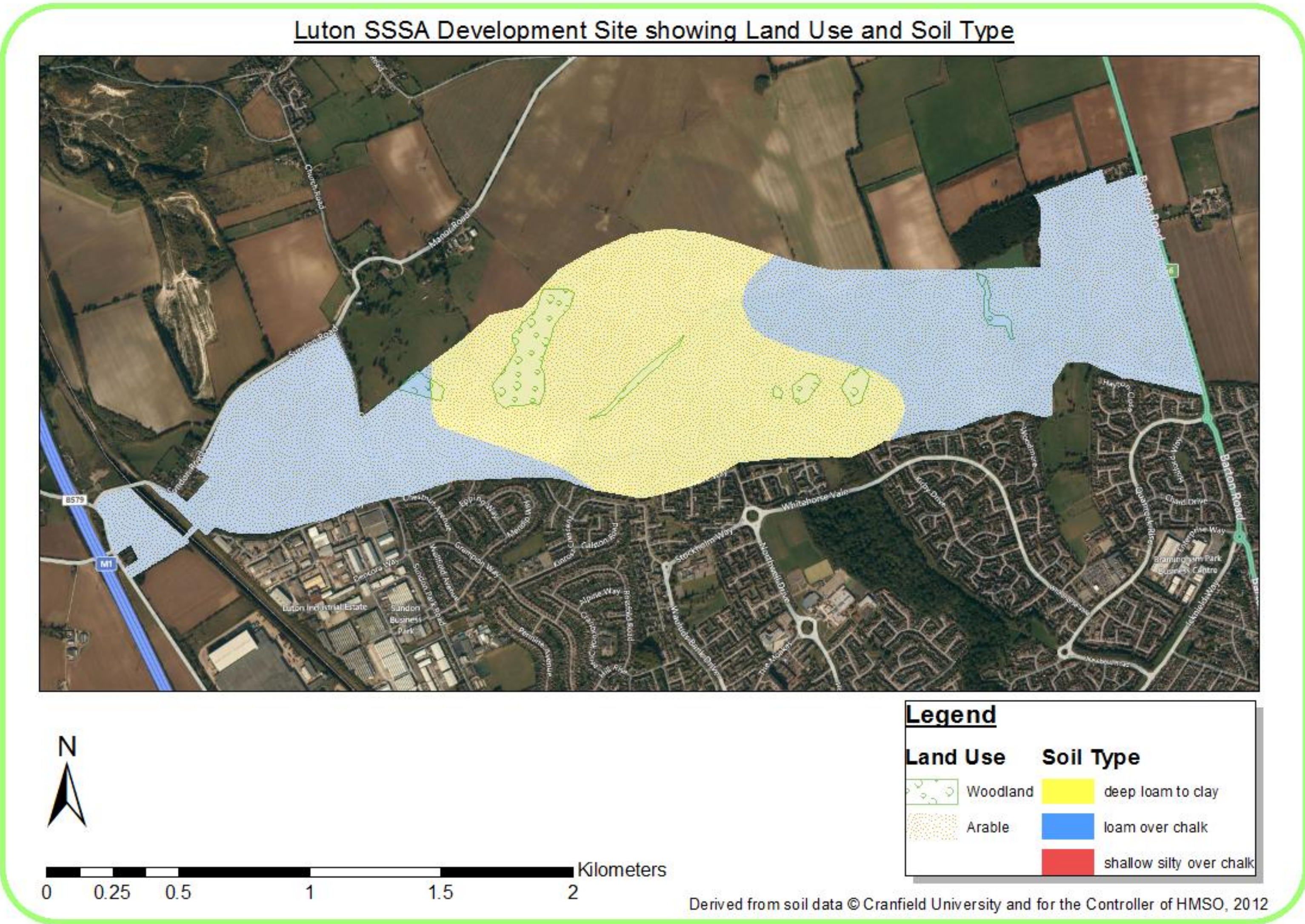

Figure E1b Soil types and land use present at the Luton SSSA development site (NSRI 2008a, b, c & 2009)

Part E1.2: Soil organic carbon

Methodology

Despite plans for the site including some commercial and open space areas, it was assumed for the purposes of the case study that the entire area will be converted to residential urban land use. Therefore, a similar method was used as with the scenario, whereby new SOC density values were assigned for each soil type, based on the mean value for that soil type under the future land use, i.e. urban residential. Since the Corine land use data was not a high enough resolution to pick up the small patches of woodland on the site, they were manually digitised and assigned new current SOC density values based on the mean value for their soil type under woodland vegetation. Then the difference between the current and future SOC density was calculated to produce a map of SOC change (t ha^{-1})

Results

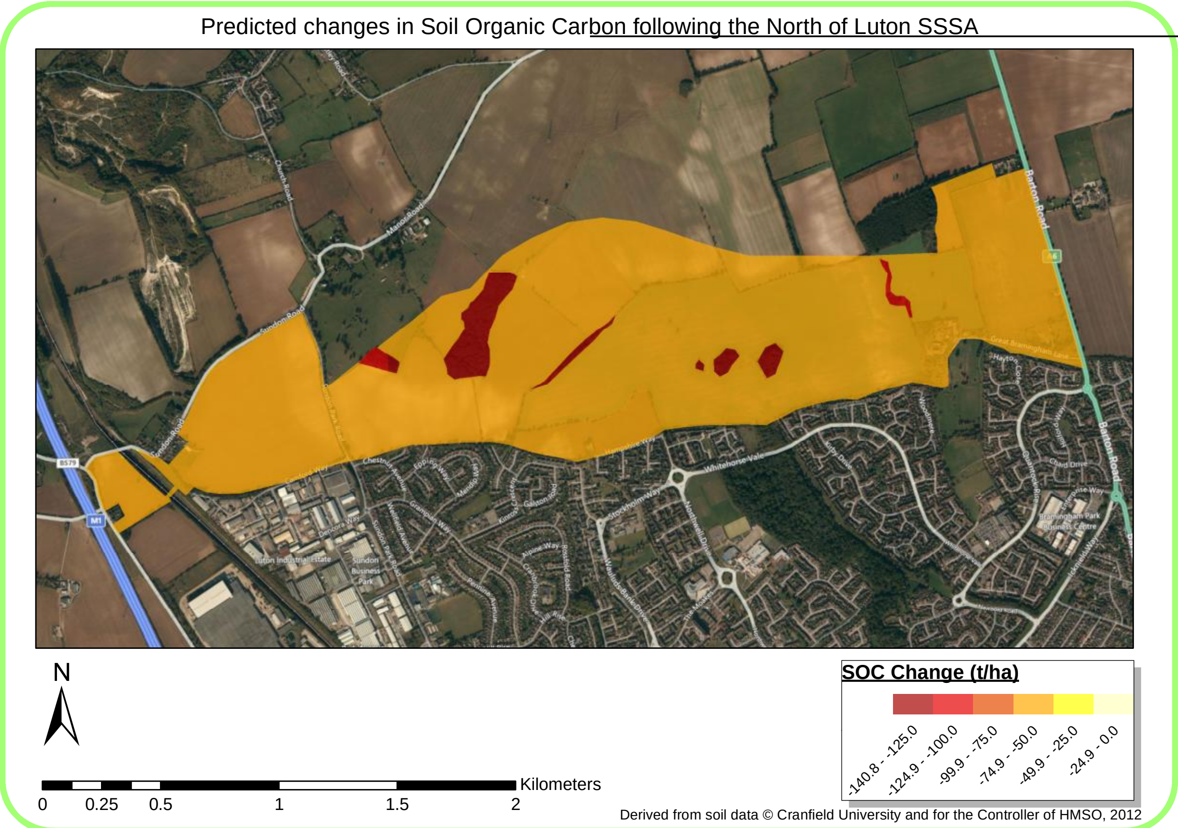

Figure E2 Predicted changes in soil organic carbon following the development of the proposed site of the North Luton SSSA.

TableE1 Initial and predicted SOC densities, and the difference between the two, for different combinations of soil type and land use in the North Luton SSSA; shallow silty over chalk was omitted due to its minimal contribution, as it takes up a very small area of the site.

Land use	Soil type	Initial SOC density(t ha^{-1})	Predicted SOC density(t ha^{-1})	SOC loss (t ha^{-1})
Arable	Loam over chalk	97.7 – 106.4	40.1	55.6 – 66.3
Woodland veg.	Loam over chalk	143.4	40.1	103.2
Arable	Deep loam to clay	117.6– 118.9	54.2	63.4 – 64.7
Woodland veg.	Deep loam to clay	194.9	54.2	140.8

Table E2 Initial and predicted SOC in tons, and the difference between the two, for the different soil types and in total for the North Luton SSSA.

Soil type	Area (ha)	Initial SOC (tons)	Predicted SOC (tons)	SOC loss (tons)
Loam over chalk	150	15614	6022	9592
Deep loam to clay	122	15179	6598	8581
Shallow silty over chalk	0	2	1	1
Total	272	30795	12621	18174

As shown in Figure E2 and Tables E1 and E2, all the soil present on the site are predicted to incur a loss in SOC following urban development. Overall, the conversion of the site from arable to urban land cover will incur a loss of 18,173 tons of SOC. The majority of the site is currently arable land and following development, all arable land would lose a similar amount of SOC, ranging from 56 to 66 t ha^{-1}; there is little variation with soil type. However, the patches of woodland vegetation would lose significantly more SOC than the arable land, with the eastern-most patch of woodland losing 103 t ha^{-1}, along with the western segment of the western-most patch, both of which overlie loam over chalk. The remainder of the woodland overlies deep loam to clay and will lose 141 t ha^{-1}.

Discussion

It is clear from the above results that it is predicted urban development will cause a drastic loss in SOC. It has been proposed by Pavao-Zuckerman (2008) that "urbanization reduces soil C in temperature regions due to accelerated decomposition and topsoil removal during development or past agriculture". Due to our method, it is impossible for urban soils not to have less carbon than other land cover types, as impervious surfaces were assumed to have 0 tC ha^{-1}. The different sub-classes of urban land cover have varying amounts of impervious surfaces, but all have some. It is possible this has led to an underestimation in urban SOC, as some research suggests urban green spaces have greater amounts of SOC than non-urban green spaces due to application of fertilisers and irrigation (Kaye et al. 2005). However, this trend tends to be found only in arid areas (Pavao-Zuckerman 2008 after Pouyat et al. 2003).

Soil under woodland vegetation contains more organic carbon than soil under arable use, therefore has more organic carbon to lose, following urban development, as was shown in the urban development scenario, see main report.

For woodland vegetation, deep loam to clay loses more carbon following urban development than loam over chalk. This appears to be because the soil has more carbon initially, so has more to lose in absolute terms (t ha^{-1}) but loses a similar proportion of its carbon, at approximately a 72% loss. However, for arable land, deep loam to clay soil loses a smaller percentage of its organic carbon following urban development than loam over chalk, with 54% and 59-62% losses, respectively. This may be due to limitations in the method, as the values applied were calculated as mean values of SOC density for each combination of soil type and land use currently present in CB from the LandIS data. Therefore, accuracy may have suffered, or some values may be less reliable than others due to variation in sample sizes used to calculate the mean values. For example, there are far larger sample sizes to calculate the arable land use values than for the other land uses, whereas for some combinations of soil type and land use there were no values at all, or just one value, so the "mean values" calculated are not as reliable.

E1.3: Runoff and soil erosion

E1.3.1 Erosion

Methodology

Due to the presence of six soil types in the case study area, The K factor varies from 0.0158 to 0.0900. LS varies across the field from 1 to 1,723 with a average of 48.0 and a standard deviation of 49.5. Erosion is here reduced by the C factor. Indeed, current land-use is wheat cultivation, which implies a C factor of 0.25 (Morgan, 2005) and under residential development, C will be reduces to 0.0094, assuming 35% of grass in the area. P and R remain constant equal to 1 and 66.14 respectively. Erosion rate was calculated within the field with a 10m resolution.

Results

The land use change is predicted to cause a reduction in erosion of 96% from 63.3 to 2.4 t $ha^{-1}y^{-1}$ (the standard deviation being 2.5 t $ha^{-1}y^{-1}$). Future erosion rate is shown on Figure E3.

Discussion

Calculated over the 261 ha of the development site, the predicted potential erosion rate would decline from 16,500 to 621 t.

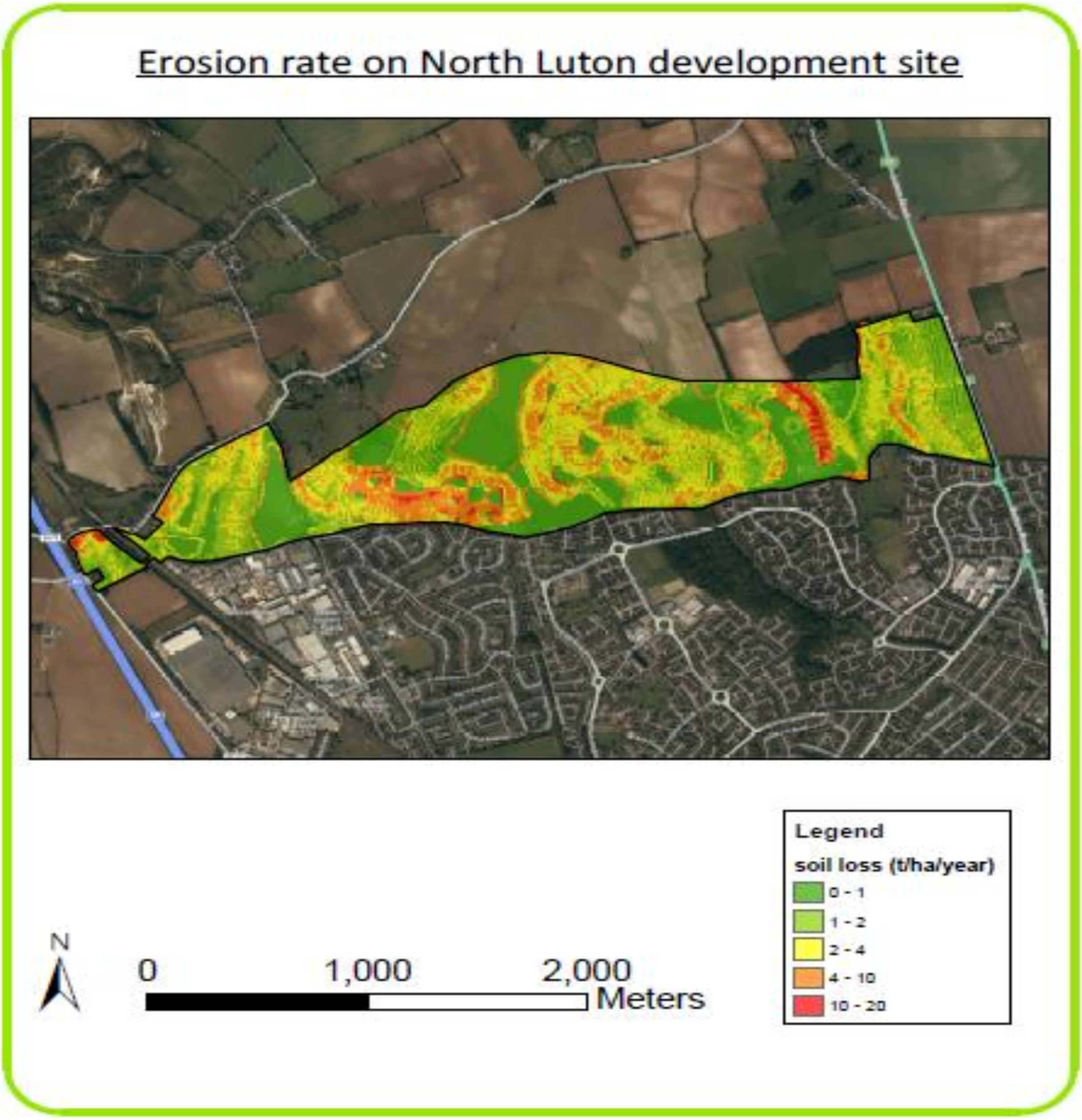

Figure E3 Predicted potential annual erosion rate for the case study development area to the north of Luton.

E1.3.2 Runoff

Methodology

Runoff generation was assessed under the Curve Number method. The site has two different hydrologic soil types. Table E3 summarises the characteristics of the three patches at stake assuming fair soil condition. Average previous wetness was assumed (condition II in the Curve Number hand book).

Table E3 Soil characteristics on residential development site of North Luton

Patch_ID	Area (ha)	Hydrologic Soil Group	Current CN (wheat crop)	Future CN (residential)
1	88.5	B	71	85
2	113	C	83	90
3	60.0	B	71	85

Results

It was found that the land use change induces a significant increase in runoff. Detailed numbers are given in table E4.

Table E4 Infiltration improvement for residential development site of North Luton

Storm event	Runoff arable (m^3)	Runoff residential (m^3)	Runoff increase (%)	Infiltration decrease (%)
worst in 10 years*	19,600	45,100	131	27.8
worst in 100 years**	42,900	80,100	86.8	32.9

*42.6mm per day, which given the area of the patch corresponds to a catch of 3440m^3
**59.7mm per day, which given the area of the patch corresponds to a catch of 4820m^3

Discussion

The results show that urban development nearly doubles runoff for a storm event. Therefore, development area should obviously be equipped with properly engineered drainage network to cope with this increase. An alternative/complementary solution to the runoff problem could be implement a good structural urban design commented previously in the urban development recommendations in the main report, section 5. As it has already been discussed in the report, the increase in runoff from new development areas is minimised by prioritising sites in locations where drainage is already naturally impeded. Sealing a sand soil would for instance mean spoiling a great infiltration potential. On the other hand building a pure clay soil might trigger other problems such as the shrink-and-swell effect that severely threatens building integrity. In the present example, 43% of the soil belongs to group C, which is of impeded drainage, but is not pure clay. Such soil is relatively suitable for development as far as the change in runoff is concerned. On the other hand, the other 57% of soil surface belongs to group B, which has a relatively good water infiltration capacity. Developing residential site on this soil is moderately suitable as far as the change in runoff is concerned.

E1.4 Water Quality

Methodology

As in the rest of this case study sections, it was assumed that the entire area is going to be converted to residential urban land use. Methodology used for the case study analysis was the same than used for the scenarios analysis, so that future leaching and overland flow risk were assigned for the different soil types under the future land use and risk variation compared to the current risk was calculated and mapped. Landuse for the different patches has been determined as in section 3b of the main report.

Results

Table E5 Initial and predicted leaching risk and the difference between the two, for different combinations of soil type and land use in the North Luton SSSA

Land Use / Soil type	Arable			Woodland		
	Mean Leaching Risk	Urban Scenario Risk	Risk variation	Mean Leaching Risk	Urban Scenario Risk	Risk variation
deep loam to clay	3	3	0	2	3	-1
loam over chalk	4	5	-1	3	5	-2

Table E6 Initial and predicted overland flow risk and the difference between the two, for different combinations of soil type and land use in the North Luton SSSA

Land Use / Soil type	Arable			Woodland		
	Mean Overland flow Risk	Urban Scenario Risk	Risk variation	Mean Overland flow Risk	Urban Scenario Risk	Risk variation
deep loam to clay	4	3	1	2	3	-1
loam over chalk	3	3	0	2	3	-1

The conversion of arable land to urban development was predicted to result in a similar level of leaching risk on the deep loam to clay soil, but a greater level of risk on the loam over chalk soil. Patches of woodland in loam over chalk soil are the ones highly affected by the land use conversion with a change of two levels going from “moderate” to “very high risk”. Conversion of arable land to urban land led to a decrease in overland flow pollution risk on the deep loam to clay soil, and no change in risk on the loam over chalk soil. Oppositely, woodland over deep clay and arable land within loam over chalk lose a level of quality by going from low to moderate (see table E6 and figure E5). No change is observed in the combination of loam over chalk soil with arable land.

Discussion and Recommendations

The greatest increased risk of overland flow from urban development occurred in a part of the study area that is currently wooded (Figure E1b). Hence it is appropriate that such woodland areas are excluded from the SSSA Urban Development Area (Figure E1a). Recommendation on how to control pollutant pathways in urban areas are given in the main report in Section 5 and 6.

Figure E4 Leaching risk variation following the Luton SSSA Urban Development project.

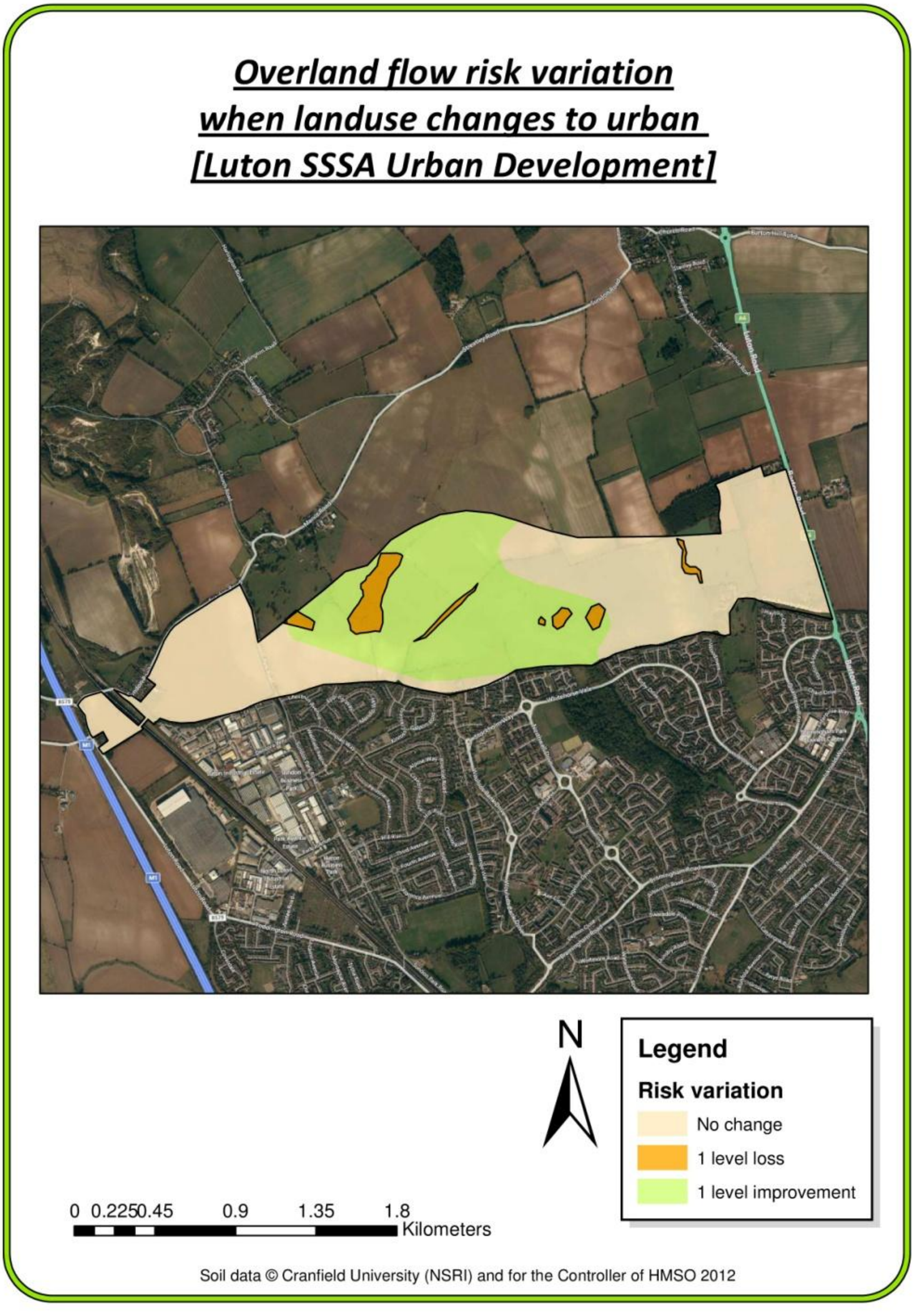

Figure E5 Overland flow risk variation following the Luton SSSA Urban Development project.

E2: Church Farm, Church Lane, Flitton (Flit River Catchment): Future land use management scenario

E2.1 Introduction

Church Farm in Flitton was selected by Hunter (2009) because the site has potential sediment and leaching problems with sandy soils, steep slopes and agriculture. The local area was first assessed to determine locations at risk of affecting the ecological quality of the river Flit. This site was chosen to measure the application of management practices to mitigate the effect of agriculture.

The farm has floodplain land bordering county wildlife sites. Flitwick Moor and Maulden Woods are both SSSI sites. Habitat categories are fragmented across the catchment and could be a target of advice to enhance natural ecosystems services.

Church Farm has a history of vegetable production going back over 70 years. Flitton Hill Organic Farm is run by the Catlin family. The farm is one of few remaining vegetable producers in an area previously known for this type of farming. The 50 acre farm was converted to organic production in 2000. In 2005 an organic farm shop was opened selling crops such as rhubarb, potatoes, carrots, curly kale and sweet corn. As of Feb 2012 Flitton Hill Organics of Church Farm are looking for a contract farmer to rent out 10 acres of the farm and the organic farm shop.

Church Farm is part of the Sustainable Organic Vegetable Systems Network Project. According to Garden Organic the farm size is 20 ha, land use intensive vegetables, altitude 60-70m and annual rainfall 440mm.

Prior agricultural land use was potatoes, brassicas, celery, leeks, runner beans and beetroot. Organic crops planned were potatoes, brassicas, celery, leeks, runner beans and beetroot. The crops were to be planted in rotation of brassicas/potatoes => Leeks => Sweetcorn / beans / celery => Grass clover ley (1 year). Church Farm’s fertility policy is grass/clover leys with farmyard manure brought in.

Church Farm (2012) confirms it is committed to improving the environment on and around the farm, restoring and planting hedge rows and trees. As part of the Countryside Stewardship Scheme, Church Farm has set aside acreage on Flitton Moor allowing it to revert to natural grassland.

The farm has organic status on the majority of the area and this limits the use of chemical fertiliser. However Hunter (2009) identifies rare wetland habitat at Flitwick Moor SSSI is experiencing deteriorating condition from the effects of river water quality. Reductions in the provision of wetland habitat could diminish the natural process of water regulation of chemicals entering the river from the land in the floodplain.

Hunter (2009) recommends buffer strips to increase the connectivity of habitat scattered across the catchment if cooperation can be achieved with neighbouring land-owners. Considerations of water quality are not a key driver of farm management practices, Hunter (2009) suggests further engagement is required.

The recommendations for management under the Organic Entry Level Scheme would be very similar to those under the Entry Level scheme (see section 4), but with an organic aspect (Natural England 2010)

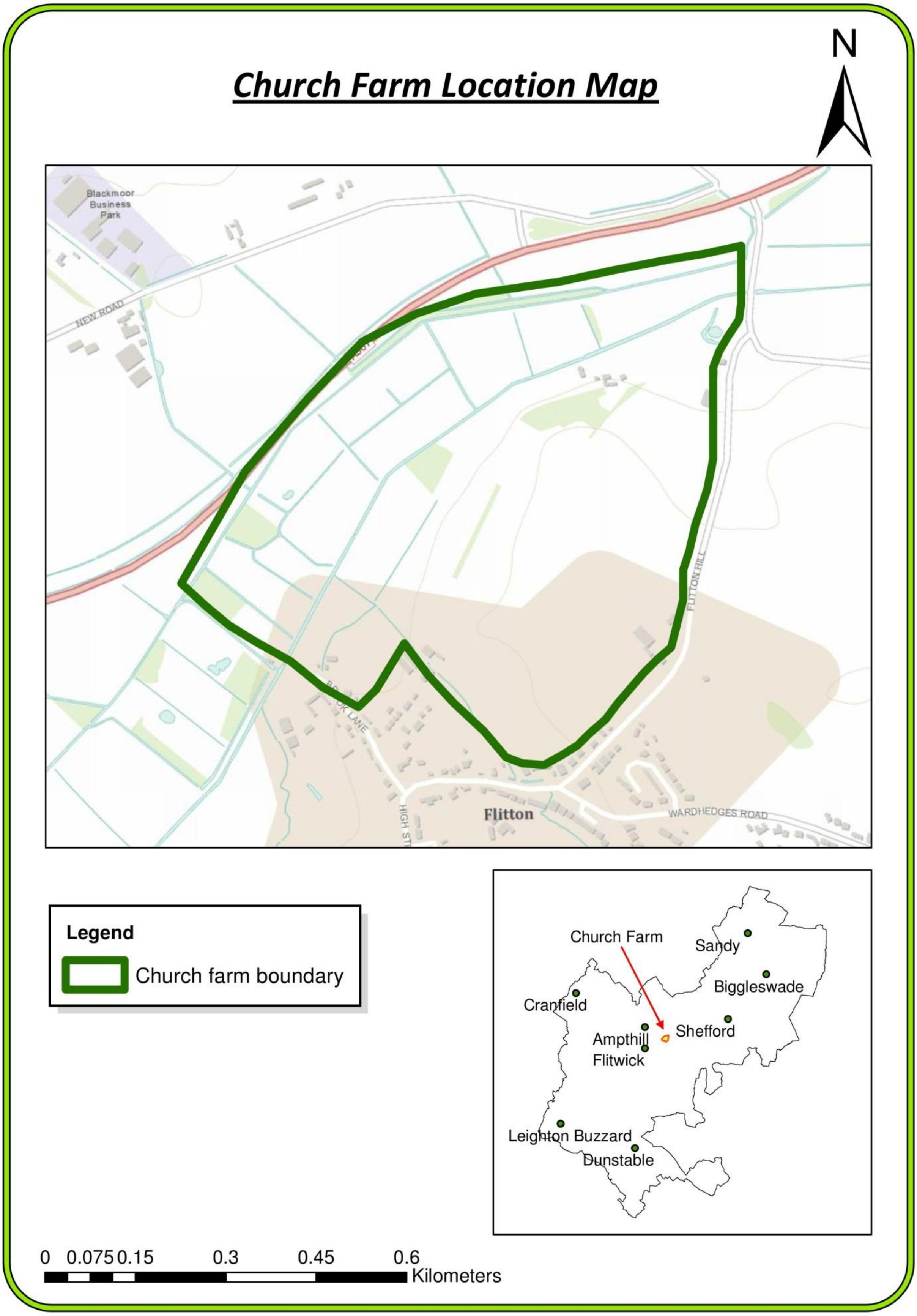

Figure E6 Location of the case study site at Church Farm, Flitton.

E2.2: Soil organic carbon

The land use at Church Farm is mainly arable/horticulture with some pasture on clay soil. The fields are separated by hedges and some grass buffer strips. The soils on which the vegetables are grown are mainly loam over red sandstone (45%) and seasonally wet deep clay (45%). A small section of deep clay (10%) occupies the south western corner of the farm on which is planted a patch of woodland (see Figure E7 below).

Figure E7 Land Use and Soil Type of Church Farm, Bedfordshire.

In terms of SOC, the following points stand out:

- Loam over red sandstone soils are relatively low in SOC, as they contain a large amount of sand. When this soil type is combined with arable land use, which also has the lowest score for carbon storage, deliberate efforts need to be made to improve SOC in this area.
- Seasonally wet deep clay soils are very SOC rich. In the case study area, this soil is shared between arable and pasture land uses. Careful management is required to ensure that SOC is not lost from this area.
- Deep clay has a high carbon stock potential, particularly when under semi natural woodland. This section of the farm also borders Flitton moor which is a Country Wildlife Site.

SOC Management recommendations for the three soil-land use type combinations:

Loam over red sandstone - Arable:

- The greatest risk to SOC is loss through erosion. Therefore any effort to minimize soil erosion on this site is beneficial to SOC as well. Ensuring constant crop cover, grass buffer strips, mulching and organic manuring are encouraged.
- Minimum or no tillage would protect the little SOC in the soils.
- Avoidance of synthetic nitrogen fertilizer and liming also reduces mineralization losses of SOC.
- Hedge rows around the fields increases area under woodland vegetation hence more SOC.
- Leaving post-harvest residue increase SOC.

Seasonally wet deep clay - pastures and arable fields

- Increasing grassland productivity by selecting improved species increases biomass productivity, and hence more litter getting into the soils.
- Minimum or no tillage protects the SOM from microbes that would otherwise mineralize it, and also reduces oxidation losses.
- Controlled grazing intensity: avoiding overgrazing increases SOC stocks.
- Reduced lime and fertilizer additions favour SOC.
- Water management to maintain SOC stocks, by maintaining anaerobic conditions.
- This would be the best site to set aside green area, taking areas out of arable use and into permanent pasture, increasing SOC stocks.

Deep clay - woodland

- Planting of native hardwood species increases above ground organic carbon and increases litter that is converted into SOC (Johnson 1992).
- Set this area aside as conservation area, also protects the neighbouring CWS of Flitton moor.

E2.3: Runoff and soil erosion

E2.3.1 Erosion

Methodology

Due to the presence of three soil types on the field, the K factor varies from 0.0306 to 0.119. The LS value varies across the field from 1 to 1909, with an average of 46 and a standard deviation of 83. The C factor was calculated as an average of variety of vegetable crops. The rotation implies that any patch of the farm will be cultivated at some point and the worst case scenario was therefore considered. C was assumed to be 0.394 for the current situation because of the crops cultivated and the surface of land that is left as 4 m contour buffer strips and hedgerows. It was assumed that good land management practices (field corners and cover crops) would be implemented across the whole farm, which decreases the C factor to 0.184 in such areas. P was assumed to be 1 for the current situation and then decreased with implementation of contouring, as explained in the erosion methodology part of this report. R remained constant equal 66.14. Erosion rate was calculated within the field with a 10 m resolution.

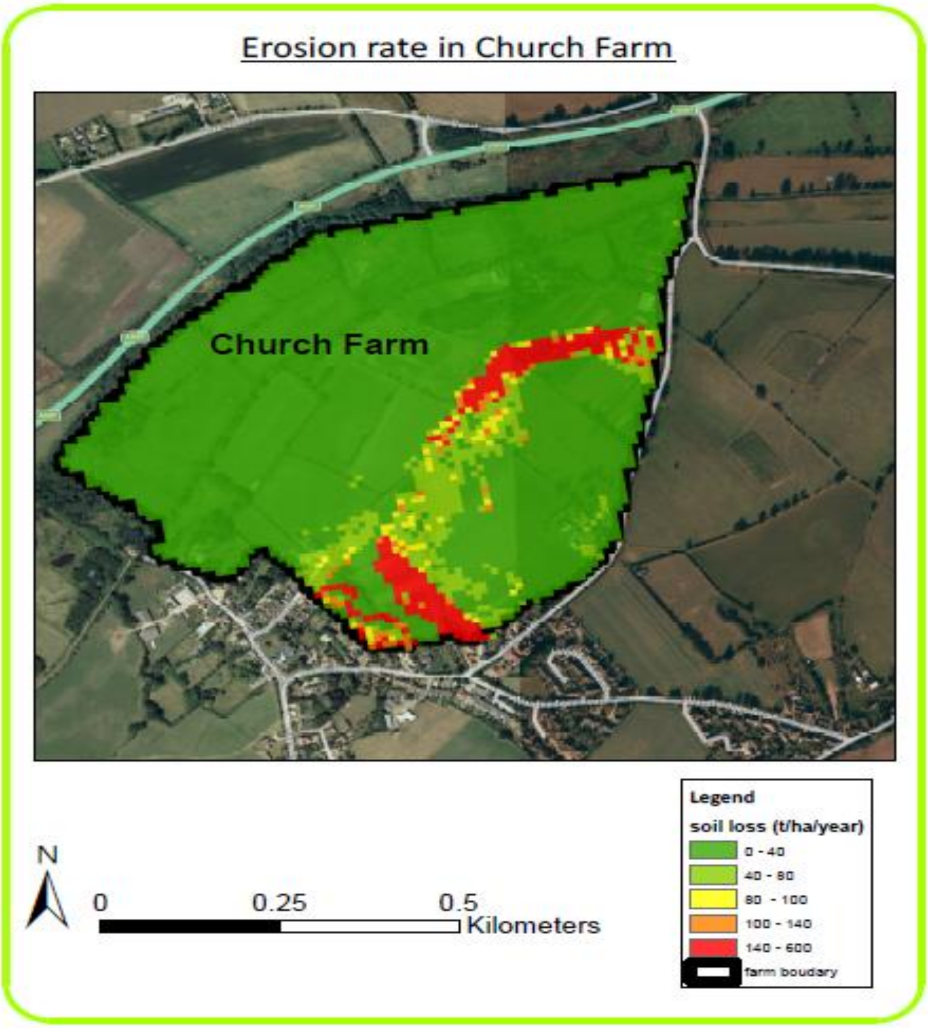

Figure E8 Predicted erosion rate with implementation of good land management practices.

Results

Figure E8 illustrate the predicted annual potential soil losses within the field. The land use change resulted in a predicted reduction of the annual potential soil loss from 3270 to 1270 tonnes per year (62%) over the 45.5 ha. This corresponds to a soil loss reduction from 5.8 to 2.2 mm/year.

Discussion

As it can be noticed in Figure E8, significant erosion is still predicted to occur on steep fields despite good land management practices. Therefore, it may be appropriate to keep the fields at greatest risk as permanent pasture, while contour buffer strips, green corners and cover crops are applied in the rest of the farm. If land use change is not possible, practices such as minimum tillage and the use of crop residues can help reduce erosion (Jasa and Dickey 1991, Quinton and Catt 2004).

E2.3.2 Runoff

Methodology

Runoff generation was assessed under the Curve Number method. The site has three different hydrologic soil types. Table E7 summarises the characteristics of the three patches at stake assuming normal distribution of the soil condition. It was assumed than the current situation involve the implementation of 4m contour buffer strips. It was also assumed that the mean field size is 1 ha, thus 4m contour buffer strips account around 15 % or the field area. Field corners, were assumed as 6 % of the field area. As was explained in the methodology of the Land Management Scenario, effects of contouring were estimated as a change in the frequency distribution of the different soil conditions. Previous wetness was estimated as average (condition II in the CN handbook).

Table E7. Soil characteristics of Church Farm

Patch_ID	Area (ha)	Hydrologic Soil Group	Current CN (conventional practices)	Future CN (good land management practices)
1	26.1	C	85.4	82.7
2	15.4	A	68.0	63.4
3	4.05	D	88.7	86.7

Results

It was found that the land use change allows a decrease in runoff (Table E8).

Table E8 Infiltration improvement for Church Farm for 2 simulated storm events

Storm event	Runoff conventional practices (m^3)	Runoff good management practices (m^3)	Runoff reduction (%)	Infiltration improvement (%)
worst in 10 years*	5040	2800	44.4	15.6
worst in 100 years**	9800	6190	36.9	20.8

*42.6mm per day, which given the area of the patch corresponds to a catch of 3440m^3

**59.7mm per day, which given the area of the patch corresponds to a catch of 4820m^3

Discussion

As shown in Table E8 the effects of land management practices on runoff seem to be significant. Most good management practices chosen for the scenario are relatively easy to implement. Although the predicted impact on runoff was smaller than in erosion, it is important to highlight that the effects of cover crops were not quantified by the Curve Number model, thus reductions should be greater (Howarth et al, 2007). On the other hand, other practices such as minimum tillage and the use of crop residues as soil cover may increase the efficiency at reducing runoff (Jasa and Dickey 1991, McIsaac et al 1991, Quinton and Catt 2004). Measures to reduce runoff and soil erosion under the ELS scheme were outlined in the main report, which showed that satisfying ELS scheme conditions can lead to a reduction in runoff and soil erosion with an associated improvement in water quality.

E2.4: Water Quality

Methodology

Since land management scenario has no significant change for water quality, there is no sense to develop a land management case study for water quality. But despite not being significant in general, could be locally, and for that reason leaching and overland flow risk were analysed and mapped.

Results

Table E9 Leaching risk for different combinations of soil type and land use in Church Farm

Land Use / Soil type	Arable	Pasture
	Mean Leaching flow Risk	**Mean Leaching flow Risk**
deep clay	-	3
loam over red sandstone	4	3
seasonally wet deep clay	4	3

Table E10 Overland flow risk for different combinations of soil type and land use in Church Farm

Land Use / Soil type	Arable	Pasture
	Mean Overland flow Risk	**Mean Overland flow Risk**
deep clay	-	2
loam over red sandstone	2	2
seasonally wet deep clay	4	2

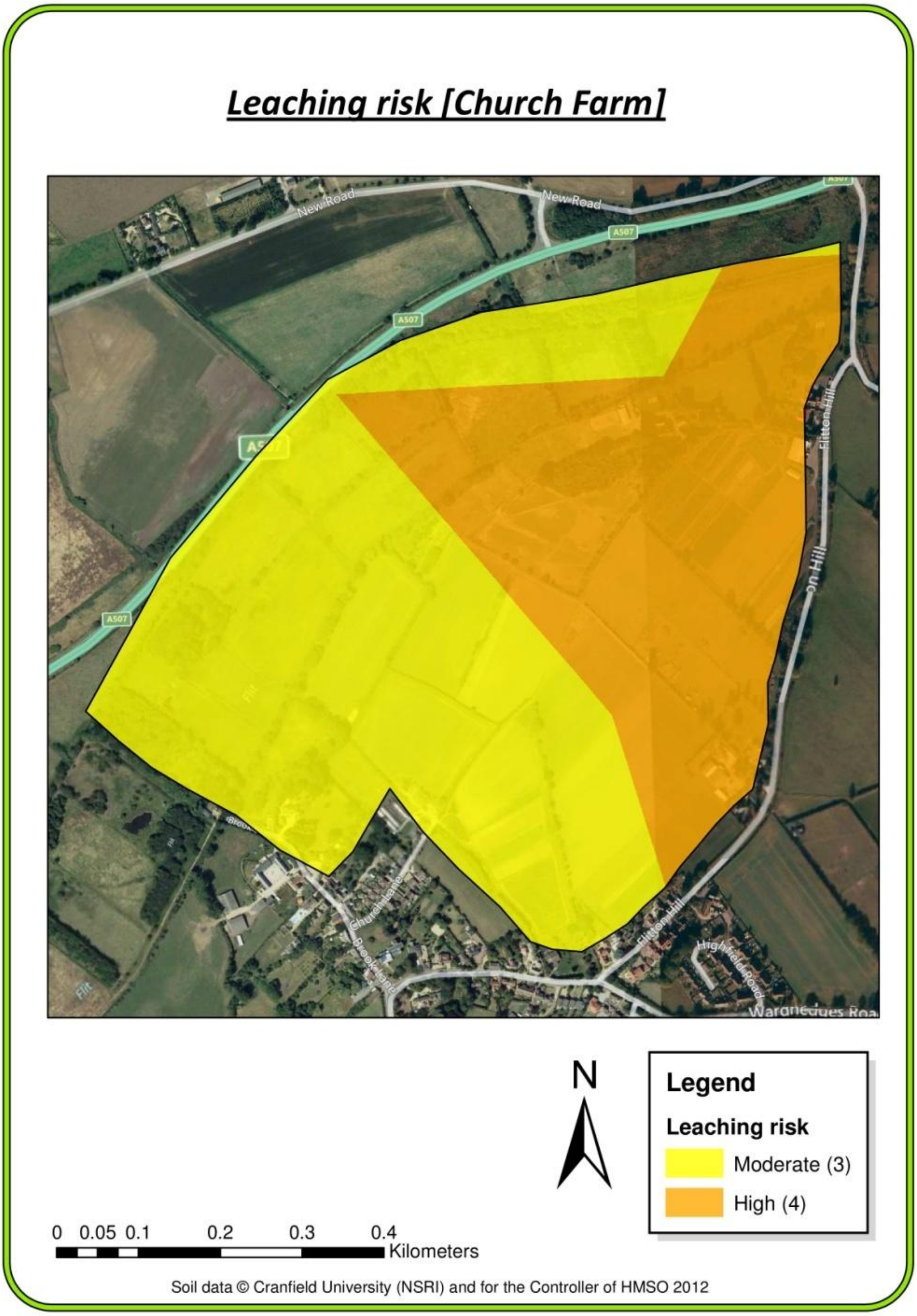

Figure E9 Leaching risk for Church Farm under current conditions.

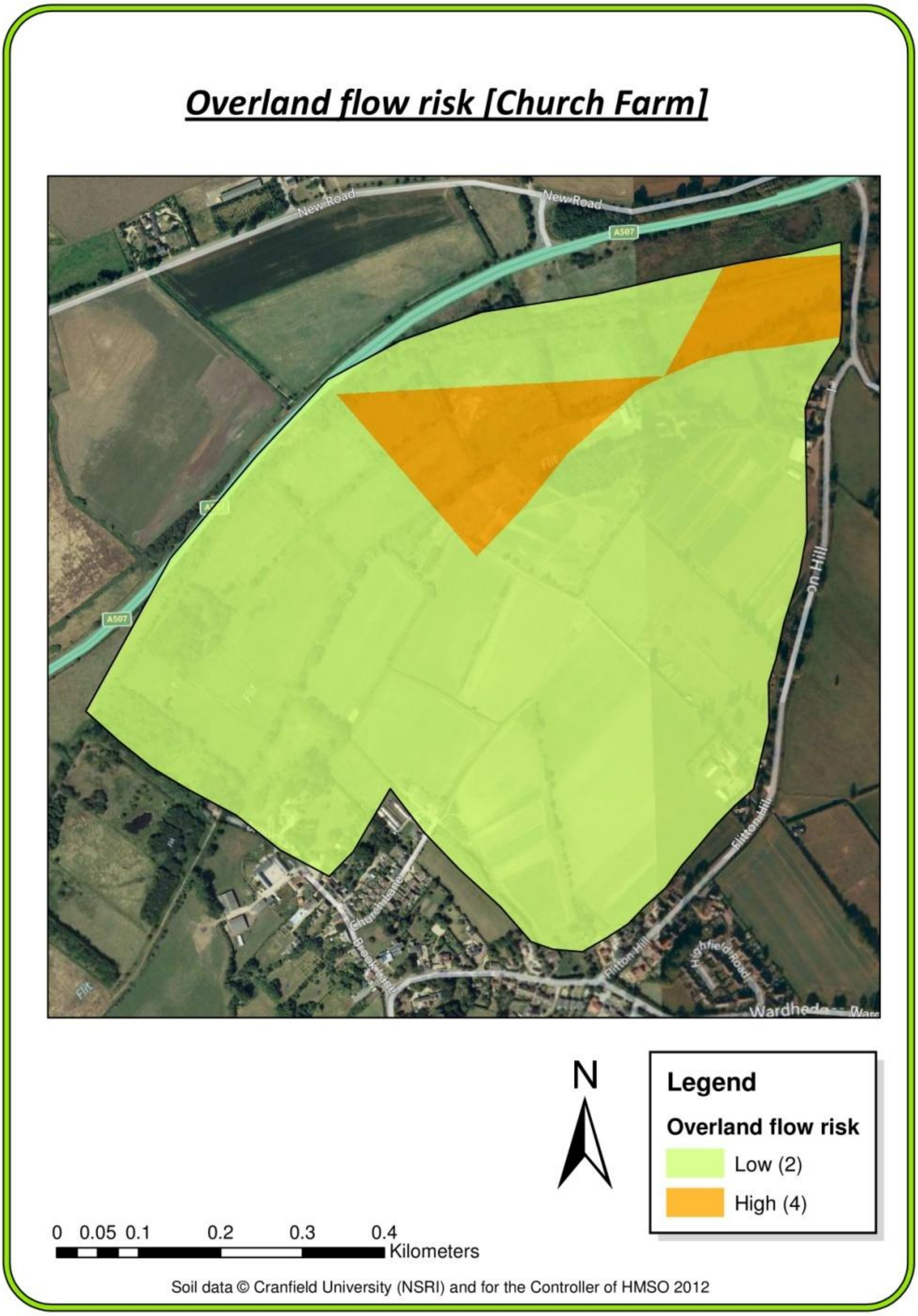

Figure E10 Overland flow risk for Church Farm under current conditions.

Compared to the arable area, the grassland areas show a lower risk level for both leaching and overland flow. Arable land on loam soils over red sandstone and on seasonally wet deep clay soils were predicted to have a high risk of pollution from leaching, compared to a moderate level of risk for the pasture. For overland flow risk, seasonally wet deep clay within arable land was predicted to be of high risk. All other combinations of soil type and land use had a low risk.

Discussion

As cited in the literature, Brady and Weil (2010) indicate that leaching is influenced by the size and configuration of soil pores. Preferential flow increases the possibility of polluting groundwater (e.g. clay has worse proprieties for water flow than sand. But if it is dried and cracks appear in it, they could become a quicker and easier way for the water to flow, and consequently pollutants) (Brady and Weil 2010). In general, sandy soils have high leaching potential for pollutants, silty soils have medium potential and clayey ones have a low potential (unless cracked) (Brady and Weil 2010). These facts can be observed in the results table for leaching risk. The low risk of pollution due to leaching from pasture, compared to arable production, is linked to the absence of pesticide risk.

Recommendations

At least some of the operation at Church Farm is currently managed in an organic way. As a certified organic producer, the farm is expected to comply with the Compendium of UK Organic Standards (2004) and any extra requirements of the chosen Certification Body (DEFRA, 2009). As an organic farm, the farm could be eligible for the Organic Entry Level Stewardship (OELS) Scheme (Natural England, 2010b). There are OELS measures (Table E11) which can improve water quality, by reducing the source of nitrates and pesticides.

Table E11 ELS/OELS management recommendations to prevent pollution at *source* and therefore improve water quality (Natural England, 2010a). Note that ↓ means reduced impact in the relative regulating ecosystem service; ↓ is reduction in impact, ↓↓ is significant reduction in impact, ↓↓↓ is dramatically high reduction in impact.

OELS [ELS] code	OES stipulation	Location	Impact on runoff (nitrate, phosphate, pesticide and sediment pathway)	Impact on soil erosion (nitrate, phosphate and pesticide pathway)	Recommendation
OU1	Organic Management	Whole field	↓↓	↓↓	No application of fertilisers, pesticides or any herbicides. Application of nitrogen sourced from animal manures limited to an average of 170kg/ha/yr (not exceeding 250kg/ha on any one field parcel)
SPECIFIC TO PROTECTING SOIL AND WATER (EJ)					
OJ2/ OJ10 [EJ2/EJ10]	Management of maize crops	Whole field	↓	↓	Same management as ELS
OJ5 [EJ5]	*Infield* grass areas to prevent erosion and runoff	Within field	↓↓	↓	Same management as ELS except that injurious weeds or invasive non-native species are to be controlled by cultivation before establishment, by cutting in the first year and by selective trimming or manual removal thereafter.
OJ5 [EJ5]	*Field margin* grass areas (buffer strips)	Edge of field	↓↓	↓	Same management as ELS except that injurious weeds or invasive non-native species are to be controlled by cultivation before establishment, by cutting in the first year and by selective trimming or manual removal thereafter.
OJ9 [EJ9]	12m buffer strips for	Close to	↓↓	↓	Same management as ELS except that injurious

	watercourses on rotational land.	watercourses			weeds or invasive non-native species are to be controlled by cultivation before establishment, by cutting in the first year and by selective trimming or manual removal thereafter.
OJ11 [EJ11]	Maintenance of watercourse fencing	Edge of field/close to watercourses	↓	↓	Same management as ELS
OJ13 [EJ13]	Winter cover crops	Whole field	↓	↓	Same management as ELS
MULTI-FUNCTIONAL: CONTRIBUTES TO PROTECTION OF SOIL AND WATER					
OB1/OB2/OB3 [EB1/EB2/EB3]	Field boundary feature: Hedgerow management	Edge of field	↓	↓	Same management as ELS
OB6 [EB6]	Field boundary feature: Ditch management	Edge of field	↓	n/a	Same management as ELS
OC4 [EC4]	Trees and Woodland: Management of woodland edges	Edge of woodland at edge or within field	↓↓	n/a	Same management as ELS except only apply herbicides to spot treat or weed-wipe for the control of injurious weeds or invasive non-native species and do not apply fertilisers or manures.
OC24 [EC24]	Tree and woodland: Hedgerow tree buffer strips on rotational and organic grassland	Within field/edge of field	↓↓	n/a	Same management as ELS except only apply herbicides to spot treat or weed-wipe for the control of injurious weeds or invasive non-native species.
OE1/OE2/OE3 OE4/OE5/OE6 [EE1/EE2/EE3/ EE5/EE6/EE6]	Buffer strips (managed as low intensity grassland): 2-6m buffer strips on rotational land and organic grassland.	Within field/edge of field	↓↓	n/a	Same management as ELS except that injurious weeds or invasive non-native species are to be controlled by cultivation before establishment, by cutting in the first year and by selective trimming or manual removal thereafter.

OE10 [EE10]	6m buffering on organic grassland next to a watercourse	Within field/edge of field	↓	↓	Same management as ELS
OF1/OL1 [EF1/EL1]	Management of arable, rotational and grassland: Management of field corners	Edge of field	↓↓	↓	Same management as ELS except that injurious weeds or invasive non-native species are to be controlled by cultivation before establishment, by cutting in the first year and by selective trimming or manual removal thereafter.
OF6 [EF6]	Management of arable and rotational land: Overwintered stubble and extended overwintered stubble	Whole Field	↓	↓	Same management as ELS.
OL2 [EL2]	Grassland: Permanent grassland with low inputs of fertilisers and sprays	Whole field	↓↓	↓↓	Apply up to 12.5tonnes/ha per year of farm yard manure, but only where grassland is regularly cut. Apply during growing season and only when field dry enough to prevent soil compaction. No other type of fertiliser or manures to be applied. If current manure and fertiliser use is less than this, do not increase applications. Injurious weeds or invasive non-native species are to be controlled by cultivation before establishment, by cutting in the first year and by selective trimming or manual removal thereafter.
OL3 [EL3]	Grassland: Permanent grassland with very low inputs of fertilisers and sprays	Whole field	↓↓↓	↓↓	Same management as ELS except that injurious weeds or invasive non-native species are to be controlled by cultivation before establishment, by cutting in the first year and by selective trimming or manual removal thereafter.

E3: Jubilee Woodland: Future BAP scenario

E3.1: Introduction

Biggleswade Woodland is one of the woodland tree plantation projects that is participating in the Jubilee woodland project by the Woodland Trust. The project aims to plant 6 million trees in the UK (The Woodland Trust 2012). The 8 ha area is located on the outskirts of Biggleswade and is located near a stream that discharges into the River Ivel (Figure E11a). The area is generally flat with an average slope of 1.30°; the surrounding area is also relatively flat. Previously, the land was used as pasture, and the surrounding area is mostly arable land. The site has loamy/clayey soil with slightly impeded drainage (NSRI 2008a, b, c) and is highly fertile (NSRI 2008a, b, c) (Figure E11b).

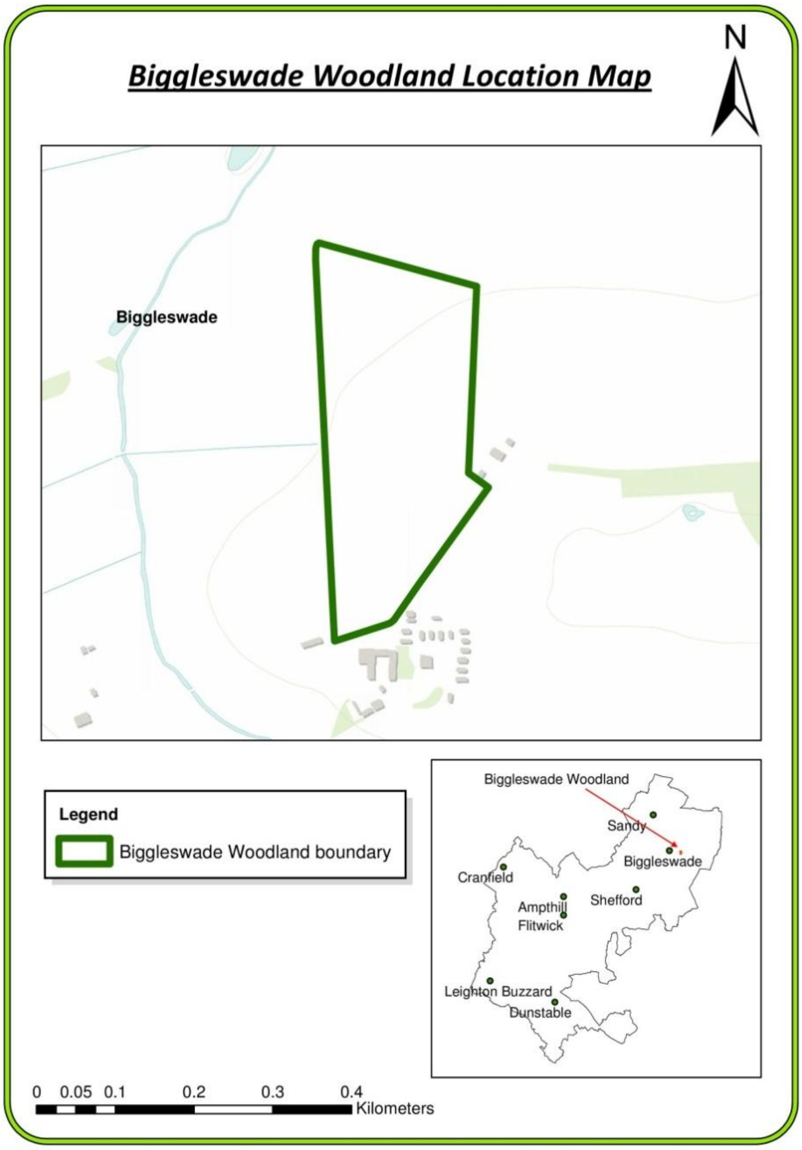

Figure E11a Location of study site at Jubilee Woodland, Biggleswade.

Figure E11b The Jubilee Woodland showing land use and soil type (NSRI 2008a, b, and c, 2009)

E3.2: Soil organic carbon

Methodology

It was assumed for the purposes of the case study that the entire area will be converted to woodland vegetation land use, and the mean value for woodland vegetation (rather than any sub-class) was used for the conversion. This was because it had values for each soil type, with no gaps. A similar method was used as with the scenario, whereby new SOC density values were assigned for each soil type, based on the mean value for that soil type under the future land use, i.e. woodland vegetation. Then the difference between the current and future SOC density was calculated to produce a map of SOC change (t ha^{-1}).

Results

Figure E12 Predicted changes in soil organic carbon following the afforestation of the proposed site of the Jubilee Woodland near Biggleswade, shown overlaid on a basemap from Bing Maps Hybrid, available in ESRI ArcGIS 10.0.

Table E12 Initial and predicted SOC densities, and the difference between the two, for different soil types at the Jubilee Woodland site near Biggleswade.

Soil type	Initial SOC density (t ha^{-1})	Predicted SOC density (t ha^{-1})	SOC gain (t ha^{-1})	SOC gain (%)
Deep clay	186	235	49	26
Deep loam	127	180	53	42
Deep loam over gravel	94	142	47	50

Table E13 Initial and predicted SOC in tons, and the difference between the two, for the different soil types and in total at the Jubilee Woodland site near Biggleswade.

Soil type	Area (ha)	Initial SOC (tons)	Predicted SOC (tons)	SOC gain (tons)
Deep clay	12	2202	2783	581
Deep loam	5	650	921	271
Deep loam over gravel	4	375	563	187
Total	21	3228	4267	1040

It is clear from the map and tables above that it is predicted there will be significant gains in SOC following afforestation of the site of the Jubilee Woodland. All three soil types will gain roughly the same amount of SOC in terms of tons per hectare, with roughly 50 t ha^{-1}each. Overall, the afforestation of the site will cause an increase in SOC of 1040 tons, increasing the amount of SOC on the site from an initial 3228 tons to 4267 tons; this is a staggering increase of nearly a third.

Discussion

It has generally been found in the literature and in this study that a conversion of arable land to woodland vegetation causes an increase in SOC. All soils present at the Jubilee Woodland site gain roughly the same amount of SOC in terms of t ha^{-1}. Therefore, afforestation of arable land is highly beneficial in terms of SOC gained.

Part E3.3: Runoff and soil erosion

D3.3.1Erosion

Methodology

Due to the presence of three soil types in the field, the K factor takes 3 different values (0.087, 0.118, and 0.123). LS varies across the field from 1 to 189 with a average of 30.3 and a standard deviation of 23.1. The C factor changes with the land use from 0.025 for pasture to 0.001 for the future forest. P and R remain constant equal to 1 and 66.14 respectively. Erosion rate was calculated within the field with a 10m resolution.

Results

Figure E13 represents annual soil loss within the field. The land use change allows to cut soil loss by 96% from 44.5 to 1.8 ton/year in the 7.91 ha field. This corresponds to a soil loss reduction from 3.56 to 0.14 t/year.

Figure E13 Predicted erosion rate under forest land cover for Biggleswade Jubilee Woodland.

Discussion

As BAP scenario, pasture scenario and woodland scenario, this case study shows that the most efficient land use to reduce erosion is the woodland. Therefore, it should be encourage in areas where erosion reduction is a priority. Moreover, well designed forests close to urban areas have a great cultural, ecological and aesthetic value (Forest of Marston Vale 2000).

Runoff

Methodology

Runoff generation was assessed under the Curve Number method. The site has three different hydrologic soil types. Table E14 summarises the characteristics of the three patches at stake assuming fair soil condition. Average previous wetness was assumed (condition II in the Curve Number hand book).

Table E14 Soil characteristics of future woodland in Biggleswade.

Patch_ID	Area (ha)	Hydrologic Soil Group	Current CN (pasture)	Future CN (forest)
1	1.58	A	58	35
2	1.93	C	82	72
3	4.56	D	86	79

Results

Applying the formulas of the SCS method (section 3), it was found that the land use change allows a 37% decrease in runoff. Detailed numbers are given in table E15.

Table E15 Infiltration improvement for Biggleswade forest creation for 2 simulated storm events

Storm event	Runoff pasture (m^3)	Runoff forest (m^3)	Runoff reduction (%)	Infiltration improvement (%)
Worst in 10 years*	932	583	37	13.9
Worst in 100 years**	1780	1120	37	21.5

*42.6mm per day, which given the area of the patch corresponds to a catch of $3440m^3$

**59.7mm per day, which given the area of the patch corresponds to a catch of $4820m^3$

Discussion

This example illustrates how efficient forest is at controlling runoff on a variety of soil types. Indeed, the land use change to forest implies a significant reduction of runoff, even when the previous use is pasture whose behaviour against runoff is considered fairly good. Therefore, woodland land use should be suggested in areas where runoff reduction is a priority.

E3.4: Water Quality

Methodology

Methodology used for analysis was the same than used for the rest of the case studies, mapping variation of leaching and overland flow risks.

Results

Table E16 Initial and predicted leaching risk and the difference between the two for different combinations of soil type in arable in Biggleswade Woodland.

Soil type \ Land Use	Arable		
	Mean Leaching Risk	BAP Scenario Risk	Risk variation
Deep clay	3	2	1
Deep loam	4	3	1
Deep loam over gravel	4	2	2

Table E17 Initial and predicted overland flow risk and the difference between the two for different combinations of soil type in arable in Biggleswade Woodland.

Soil type \ Land Use	Arable		
	Mean Overland flow Risk	BAP Scenario Risk	Risk variation
Deep clay	3	2	1
Deep loam	3	1	2
Deep loam over gravel	2	1	1

Figure E14 Predicted leaching risk variation following the Jubilee Woodland project.

Figure E15 Predicted overland flow risk variation following the Jubilee Woodland project, shown overlaid on a basemap from Bing Maps Hybrid, available in ESRI ArcGIS 10.0.

Table E16 show that deep loam and deep loam over gravel have a high leaching risk compared to deep clay that has a moderate level. A land use conversion to woodland means a general improvement for leaching risk in the whole area, much more noticeable in the case of loam over gravel that enhances 2 levels, to a low risk.

A similar situation is observed for overland flow, but with different characteristics (figure E15 and table E17). Deep clay and deep loam show a moderate risk, worse than the low risk showed by loam over gravel. Conversion to woodland also means improvement for overland flow risk. In this case, deep loam is the soil type with the greater improvement, 2 levels, compared to the improvement of one level for deep clay and deep loam over gravel.

Discussion

As the current land use is the same for the whole area, differences in the risk of both leaching and overland flow can be attributed to soil type.

Arable areas are characterised by the use of chemicals (pesticides and fertilizers) which means that all the possible pollutants are present in the area.

The higher leaching risk for loam and loam over gravel can be justified by soil particles and soil pores size, which are larger for loamy soils than for clayey soils (Brady and Weil 2010). This fact could also justify the greater risk of overland flow for deep clay and deep loam due to clay particles smaller size and loam intermediate size what which allows easily transportation within runoff.

A general improvement in both the risks of leaching and overland flow is observed when the BAP is implemented at this site, converting the area into woodland. For both risks, change could be due to the absence of chemicals in woodland management, and specifically for overland flow risk as a result of the improvement of vegetation cover what reduces erosion and runoff velocity contributing to infiltration.

Recommendations

The planned conversion of the area to woodland is beneficial with regards to water quality.