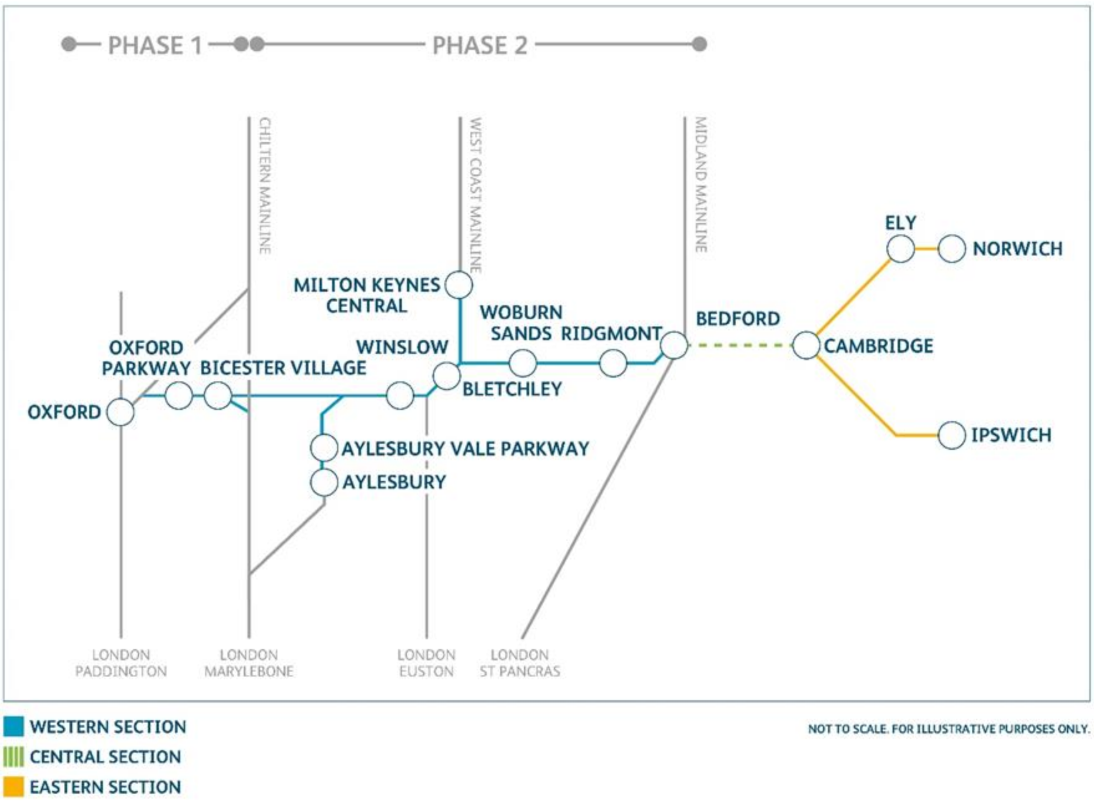
A NATURAL CAPITAL BASED APPROACH TO INFRASTRUCTURE SITE SELECTION AS APPLIED TO TRANSPORT ROUTES



Cranfield University

School of Water, Energy and Environment

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CRANFIELD UNIVERSITY

A Natural Capital Based Approach to Infrastructure Site Selection as Applied to Transport Routes

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Executive Summary

The East-West Rail Consortium (EWRC) aims to join urban areas in the south and east Midlands with East Anglia, creating a link between Norwich, Cambridge, Bedford, Milton-Keynes and Oxford. The development of this 'Oxbridge' corridor area is divided into three sections: Western, Central and Eastern sections. Within each section, important demographic growth is expected and would need to be supported through creation of new settlements, jobs and infrastructure. This represents an opportunity to design new, well-connected communities, whilst respecting the environment and its resources.

This project focuses on the 'Central' section development between Bedford and Cambridge. It is included within the aspirations of the 'Bedfordshire Local Nature Partnership', who encourage and promote the emergence of green economy principles through connecting inhabitants with nature and environmental protection.

This project, took place between March and May 2018 with the aim of providing a visual overview of the advantages and disadvantages associated with a range of route options for rail infrastructure connecting Bedford and Cambridge. This overview sought to address every stakeholder connected with the rail proposals and offers creative resources for policy makers.

Interviews, background research and field trips, provided an initial insight of the situational requirements. These methods preceded a land cover valuation of the area of interest. In order to find the best option to connect Bedford to Cambridge, three rail line options were drawn. Firstly, a proposed route by EWRC was defined, following the advice of Bedfordshire Local Nature Partnership (LNP). This is a straight route between Bedford and Cambridge. During the trajectory, Bedford and Sandy are provided with new train stations on the surrounding urban fringes, similar to the example at Oxford Parkway. Secondly, and accordingly to National Infrastructure Commissions (NIC) future plans for the area (NIC and SQW, 2017), a second route was derived by the 5th Studio spatial design agency. This route is appropriately named as the 5th Studio route. Contrastingly to the first route, 5th Studio have commenced their route from Marston Moretaine. Moreover, the strength of the suggested route, in particular, is focussed on the new stations planned for Sandy, between Sandy and Cambridge and at Addenbrookes, South of Cambridge. This will compliment any further planned

infrastructure such as the development of new houses in the area. Finally, a third route was suggested by the Cranfield project team, also referred to as the Northern Route. This route is covering the northern part of the study area providing additional transportation options for St. Neots and Cambourne.

The two previously developed routes could be compared and contrasted. However, in order to gain and provide a sound analysis for evaluating each route a third route was drawn providing a platform for undertaking a natural capital approach to infrastructure site selection. Consequently, all three options were analysed to realise a natural capital assessment. Each option has been assessed on a financial and factual basis to identify creative opinions about changes in land use. Appropriate communication of findings forms an important part of this project with the primary aim to advise decision makers over the future ‘Central’ section of the Oxbridge corridor.

This report highlights the importance of infrastructure planning and development and is completed by the use of tools such as map-based software, for performing the environmental valuation of land cover with the area. The chosen method provides a per-hectare valuation of different types of areas potentially crossed by a rail line. The calculations were based on an ecosystem service valuation of the land cover types affected by the proposed routes. To assess the extent of environmental disturbance, the per-hectare value of different zones was multiplied by the area permanently disturbed by the railway infrastructure. The main sources assessed for the valuations are those related to the current ongoing High Speed 2 (HS2) project as well as those already quoted by the United Kingdom National Ecosystem Assessment (UK-NEA) and Department for Environment, Food and Rural Affairs (DEFRA).

The projects final outputs include a map for each proposed route based on the 22-meter track requirement. Individual maps are presented for specific land covers including woodlands, wetlands, grasslands and arable land. Land cover mapping, a layer available from Digimap, was used for developing the final outputs. Further demonstration is evident through the use of flood risk and digital elevation models (DEM), which aided the site selection for the Northern Route. Once decided the implementation of tunnels, bridges and noise barriers was undertaken with the outputs illustrated within the report. All maps underwent processing whereby the maps were clipped and edited using ArcMap and Google Earth. All maps were published on ArcGIS Online presenting a method for adapting and overcoming any restrictions.

Throughout the study particular attention was directed towards the land take and consequential impact that development of railway infrastructure will have on the study areas' natural capital and surrounding environment. 5th Studio have presented a route that results in the shortest distance to build with the least construction pollution. More importantly this route has the least impact on natural capital in comparison to the other two suggestions.

Both atmospheric and sound pollution were a key focus of the project. The length of 5th Studio's route also coincides with the least atmospheric pollution. Unlike the Northern Route, which results in the greatest pollution due to the longest length of build. Potential engineering costs were attributed to each route. The Northern Route is the longest and requires four bridges and regular noise barriers. Although substantial engineering is required the Northern Route is the cheaper option of the three. Noticeably, the Northern Route will have a greater impact on currently populated areas compared to 5th Studio's suggestion, whose route provides the least impact of the three. The greatest impact on populated areas, as well as the greatest cost of landowner compensation, comes from the EWRC proposal with costs exceeding £65.3 million. Although such considerable costs are presented, this route is the shortest and subsequently the quickest journey time is ascribed.

Each route is seen to have benefits and disbenefits whether related to natural capital, engineering and compensation costs or removal of recreational areas. The study has proved insightful in relation to the necessary frameworks, tools and metrics that can be utilised when undertaking a natural capital approach. Cranfield University has provided a proof of concept that has addressed the opportunities and constraints with the construction of the 'Central Section' of East-West Rail (EWR)

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List of Abbreviations

ASNW	Ancient Semi-Natural Woodlands
BAP	Biodiversity Action Plan
C&D	Construction and Demolition
CO_2	Carbon dioxide
CPAWS	Conifers and Plantations on Ancient Woodland
CU	Cranfield University
dB	Decibel
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
EA	Environment Agency
ECML	East Coast Main Line
EFTEC	Economics for the Environment Consultancy
EWR	East West Rail
EWRC	East West Rail Consortium
FC	Forestry Commission
GHG	Greenhouse Gas
HS2	High Speed 2
km	Kilometre
LNP	Local Nature Partnership
LNR	Local Nature Reserve
m	Metre
MEA	Millennium Ecosystem Assessment
min	minutes
NCA	National Character Area
NIC	National Infrastructure Commission
NPA	National Park Authorities
ORVal	Outdoor Recreational Values
PAWS	Plantation on Ancient Woodland Sites
RSPB	Royal Society for the Protection of Birds
SSSI	Site of Special Scientific Interest
SUDS	Sustainable Urban Drainage Systems
UK	United Kingdom
UK-NEA	United Kingdom National Ecosystem Assessment
WCF	Woodland Carbon Fund
WT	Wildlife Trusts

1 Introduction

Cambridge, Milton Keynes and Oxford are some of the United Kingdom's (UK) most productive and fast-growing urban areas. The Oxford-Milton Keynes-Cambridge arc is home to 3.3 million people. However, to maximize its economic potential, up to one million new homes will need to be constructed by 2050 (NIC, 2017)

The arc extends around 130 miles from Cambridgeshire, via Bedford and the southeast midlands, to Oxfordshire. Important towns including Luton, Northampton or Daventry among others are enclosed in the area. Currently, the largest urban areas within the arc are connected with London via frequent and direct rail services (less than 60 minutes) and within an hour's drive of an international airport. Whereas, the train connections between the towns and cities, especially from east to west, are relatively poor, requiring extensive travel via London. For instance, it is not possible to travel directly by rail between four major rail stations; Oxford, Milton Keynes, Bedford and Cambridge. The only public transport link is provided by the X5 coach service, and it takes nearly three and a half hours to travel between Oxford and Cambridge (NIC, 2017).

It is estimated by the National Infrastructure Commission (NIC) that the area could support around 335,000 new jobs by 2050 (NIC, 2017). Consequently, the economic outputs will increase by approximately £85 billion per annum with a requirement of between 23,000 and 30,000 new homes per year (NIC, 2017). Therefore, in spite of the areas potential profitability, the infrastructure growth within the arc is under considerable pressure. On one hand, the area is not building enough homes to meet current and future needs, therefore, they have a low affordability. On the other hand, the arc has limited access to labour that is exacerbated by poor east-west transport connections.

Access to rail and road connections will be essential in supporting the growth of new settlements and general sustainability of the area. Therefore, the east-west rail (EWR) service will play a vital role in unlocking the arc's potential.

When designing the rail lines, it is important to balance journey times, stations and service frequency among other important factors so as to fulfil peoples' needs. The rail line should cover the growth opportunities areas such as Marston Vale, Sandy and

Addenbrookes where new housing and associated infrastructure can be developed (NIC, 2017).

However, the development of the arc should not compromise the high quality of the environment. Government and local authorities should ensure that the planned infrastructure is developed to achieve net gains in both biodiversity and natural capital.

Natural capital can be defined as “the world’s stocks of natural assets which include geology, soil, air, water and all living things” (Natural Capital Scotland, 2017). Natural capital provides a resource from which humans can gain a wide range of ecosystem services. According to Costanza *et al* (1997),“The ecosystem services consist of flows of materials, energy, and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare”. Those ecosystem services are classified, according to the Millennium Ecosystem Assessment (MEA), as “Provisioning” (the product obtained from ecosystems like food or fibre), “Regulating” (benefits obtained from regulation of ecosystem process such as water or disease regulation), “Cultural” (non-material benefits provided by the ecosystem such as recreational or educational services) and “Supporting” services (those services necessary for the production of the other ecosystem services such as nutrient cycling) (Watson *et al.*, 2005, fig. 2.1).

The aim is to provide a proof of concept that aids with the area’s assessment. This will be attained by quantifying the ecosystem goods and services held within the site’s natural capital assets. Financial values and assessment methods are attributed to key areas as a means of unified comparison providing stakeholders with a set of tools for minimising the environmental impact of the ‘Central Section’ of EWR. Current route proposals which could connect Bedford to Cambridge will be considered, focusing primarily on the areas’ natural capital and the cost likely to occur through disruption of such affected area

For the purpose of this study, a route will be suggested by Cranfield project team. The route will aim to minimise the impact on natural capital through extensive research of the area and its potential future requirements. The calculation of natural capital costs will enable the assessment of the benefits or disbenefits of each route, eventually leading to the drawing of conclusions based not only on natural capital but other important factors such as; journey times, construction costs, and likely constraints and solutions.

1.1 Study Area

The study area of this project is found in the counties of Bedfordshire and Cambridgeshire, in the east of England. The authorities who cover the area are: Bedford Borough Council, Central Bedfordshire Council and South Cambridgeshire Council. The study is mainly focused around the future proposed rail line connection between the major urban areas of Bedford and Cambridge. Moreover, the routes will aim to improve commuter links for the towns of Sandy and St. Neots.

International and national companies are located within the area with particular awareness of the current expansion of Milton Keynes. Additionally, Cambridge University, ranking as one of the best of the world is also within close proximity to Bedford and Milton Keynes.

Consequently, the urban areas within the study area have a key importance for the future development of the Cambridge – Milton Keynes – Oxford arc. The infrastructure required for this transition is likely to be delivered through initially developing the East–West Rail line and stations, followed by an accompanying Oxford-Cambridge Expressway, with an eventual target of the creation of a million new homes by 2050 (NIC, 2017).

The main towns and cities of the study area currently have access to northern and southern urban areas via road and rail infrastructure such as the East Coast and Midland Main Lines and the M1 and M11 motorways. However, an evidential lack of accessibility to eastern and western urban areas has led to the creation of the aforementioned proposals and their fundamental requirement of improving east to west connections.

The Bedford to Cambridge connection is the final construction phase of the East - West Rail network, providing a direct link between the cities of Norwich, Ipswich and Oxford. The key benefit of this proposed network is the avoidance of routing through the City of London, where lengthy commuter times are born. For the benefit of context, densely populated, urban settlements and their position within the study area and the UK are shown in Figure 1-1, with major and minor rail line stations emphasised.

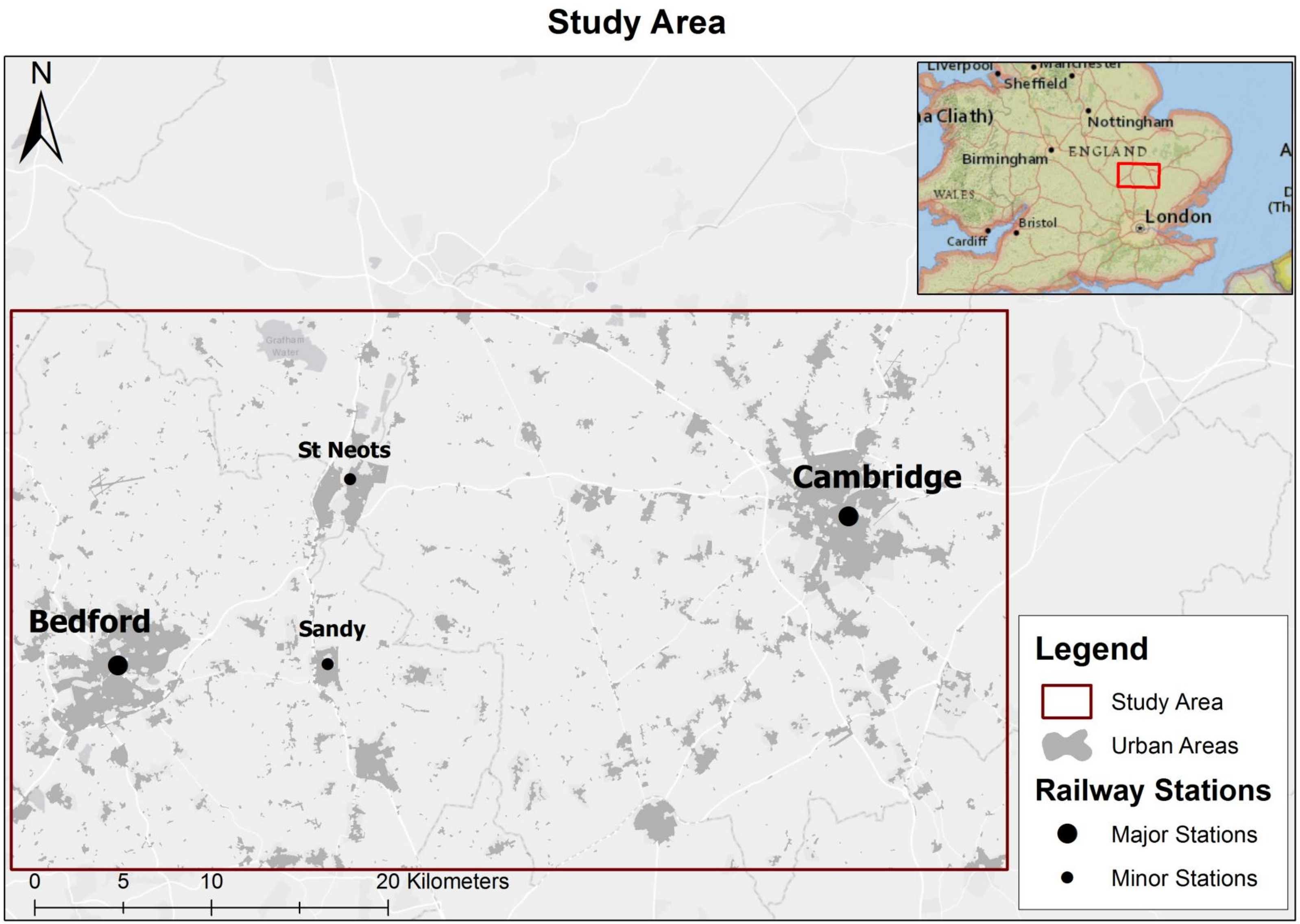

Figure 1-1: Study area representing the main urban areas.

1.2 Study Area Characteristics

The relict post-industrial landscape of the Bedfordshire and Cambridgeshire claylands has undergone transformation into a modern-day wildlife haven. Gravel and clay pits of Marston Vale have undergone remediation and have been restored as water bodies. Although the landscape would have looked different to how it does now, the development of secondary woodland and plans for further expansion of the community Forest of Marston Vale will result in an evolving and flourishing future environment.

Marston Vale, as aforementioned, was a heavily industrialised area due to the rich mineral deposits found in the area. Unfortunately, not all former workings have been given back to the landscape and landfill sites are numerous within the area. Brogborough and Stewartby are the main sites. However, they are now closed and have been capped, allowing the use of methane extraction technology to provide some benefit from their existence.

The River Great Ouse travels through the study area providing riparian and wetland habitat that is ideal for overwintering birds, who may utilise the riches for a breeding ground. Additionally, otters, and protected species including the great crested newt and water vole are known to reside within the area. Water is a prominent, but a scarce resource in the area. Information provided in the National Character Area (NCA) profiles: 88 and 90, frequently refers to water availability and limitations (Natural England, 2014a, 2014b). Presumably this is due to the low rainfall in the area. Further, it has been stated that future development will result in increased pressure on the already limited water resources (Natural England, 2014a). Surprisingly, based on the previously mentioned restrictions, Bedfordshire and Cambridgeshire Claylands have three underlying aquifers and a fourth within the Greensand Ridge.

The land cover of the study area is predominantly arable agricultural land. However, coniferous planting, deciduous woodland, heathland pasture and arable farmland are habitats found in the lower regions of the study area. Whilst on the elevated Greensand Ridge, acid mires, traditional flood meadows and wet woodlands provide niche habitats and corridors (Natural England, 2014b).

Throughout the study area, young and old plantations alongside ancient woodlands are evident, with the older woods occurring largely on boulder clay. Species found throughout the study area include; Sweet chestnut (*Castenea sativa*) as well as conifers are seen to thrive on the sandy nutrient poor soils on the edges and upper areas of the Greensand Ridge. Sessile oak (*Quercus petraea*), birch (*Betula*), holly (*Ilex*), rowan (*Sorbus aucuparia*), small-leafed lime (*Tilia cordata*), bracken (*Pteridium aquilinum*) and bluebells (*Hyacinthoides non-scripta*) are observed on the lowland plateaus. Numerous rare species of fungi are found throughout the habitats of the Greensand Ridge (Natural England, 2014b) The habitats within the study area are particular havens for biodiversity especially wild orchids. Conservationists have recorded 27 species of orchids within Bedfordshire alone. With less than sixty species known to exist within the UK, the county of Bedfordshire provides an ideal range of habitats to ensure their continued survival and success (Greensand Trust, 2018).

Noteworthy, at this stage is the particular concern related to woodlands. Concern is raised due to the numerous likely crossings of Sites of Special Scientific Interest (SSSI) when constructing the EWR line. These include, but are not limited to; Gamlingay Wood, Waresley Wood, Eversden and Wimpole Woods. Local Nature Reserves (LNR) such as; Fenlake Meadows, The Riddy and Byron's Pool are also of concern. Further, The Wildlife Trusts (WT) sites that are at risk include, Cople Pits, Gamlingay Cinques, Waresley and Gransden Woods, Cambourne Nature Reserve, Hayley Wood and Trumpington Meadows.

2 Methodology

The following section describes the methodology implemented for the achievement of the study. As can be seen in Figure 2-1 the study consisted of four main steps. The research from which the detailed methods have been developed initially came from a literature review, followed by the creation of maps and subsequent area analysis. Route development allowed for an estimation of each route's requirements. This enabled an understanding of the potential effects that are likely occur to both the environment and the areas' natural capital assets.

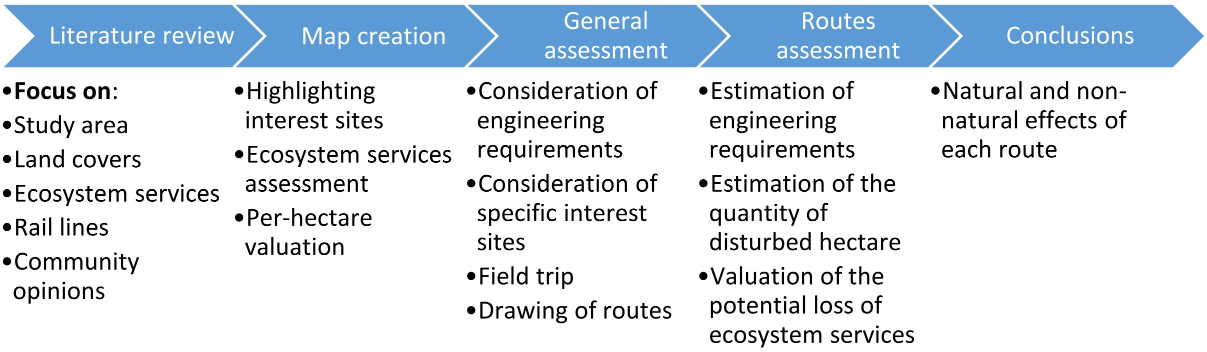

Figure 2-1: Methodology Process.

A literature review was conducted whereby collection of documentation on which the project is based was assimilated. Research commenced on selecting a suitable methodology to acquire relevant information about the projects study area such as, land covers, ecosystem services, rail lines and community opinions. The literature research started with an analysis of HS2, which is a future high-speed rail line connecting London, Birmingham, Manchester and Leeds. This HS2 project is further advanced than the East West Rail and has served as a support for data research and conclusions throughout this report. On the other hand, the UK-NEA provided an analysis of the natural landscape of the UK. It presents different land covers as ecosystems offering various services for society. Those services can be categorised as supporting, regulating, provisioning or cultural. This project was inspired by UK-NEA for dividing a map into land covers and evaluating them by services, whereas the HS2 example was exploited to understand and gain precise requirements and highlight potential issues with the development of the EWR line.

Analysis of the territories affected by a rail line development, particularly near the Greensand Ridge, was undertaken through the use of a natural-capital approach. A spatial database of the area was created, that included data relevant to the analysis. In parallel, the ecosystem services offered by different land covers, were emphasised. To level those services and compare their importance, a per-hectare financial value was given to them.

Different land covers were identified in the study area. Figure 2-1 highlights the main land cover types: arable and horticulture, neutral grassland, improved grassland, acid grassland, calcareous grassland, heather grassland, heather, broadleaf woodland, coniferous woodland, fen, marsh and swamp, freshwater, inland rock, urban and suburban. The land covers of: arable and horticulture, neutral, improved and acid grassland, fen, marsh and swamp, fresh water and broadleaf and coniferous woodland were selected due to their environmental and economic relevance. The other land covers were not at threat from any of the route's proposed. Urban and suburban areas were quantified using data from GOV.UK (2018) and Land Registry (2018) sources.

Different versions of the land cover map were created from the general land cover map demonstrated in Figure 2-1. A map of each land cover, woodland, wetland, grassland and arable was created utilising a one-mile proximity zone for each route.

Agricultural land classification maps were used to identify the arable land grades. Due to this map being obtained from another source, two map sheets were joined to give the grade of the area crossed by each route enabling an accurate land loss assessment (Figure 2-2).

A Digital elevation model (DEM) was used in the selection of the Northern Route and the placement of tunnels (Figure 2-3). Moreover, the study area has many areas susceptible to flooding. These areas are classified as Zone 3 (>1% of flooding occurring from rivers). UK rail lines are affected by flooding every year. Repairing of damage caused by flooding is a costly process and avoidance of such areas is advisable, where possible.

The cost of damage due to adverse weather condition is already substantial and it is expected that increases will be seen in the future due to the changing climate, leading to more disruption to rail operations, more damage to rail lines and associated infrastructure assets, and greater negative impact on people's health and wellbeing.

Figure 2-4 shows the flood map for the study area. It will be difficult to avoid all of them, when constructing a rail line that connects Bedford to Cambridge. The greatest risk is in areas with an elevation lower than 20 meters. Therefore, a solution could be to construct bridges or elevated rail lines through these areas.

A general assessment of the area was undertaken of the two already developed routes and the third route developed by the Cranfield project team. The Northern Route was created following engineering requirements and avoiding, when it was possible, SSSIs, for natural and cultural reasons. Development of the Northern Route included field visits which were used for familiarisation of the topography, land covers, cultural assets, existing extent of urban development and an identification of limitations to routing of a new rail route. In addition, group meetings with stakeholders helped to outline the project process. Analytical tools were gathered to help visualise the current and future situations for the project. Consequently, the drawing of the three options for the future rail line development were carried out (Figure 3-1).

The three selected routes were then assessed. Their specific features helped in estimating their particular impact on natural and non-natural capital. The method followed was the multiplication of disturbed areas of land covers by the per-hectare valuation of their benefits. The potential disturbance of each route was assessed according to the tool that was created for evaluating the impacts on the natural capital of both Central Bedfordshire and South Cambridgeshire. For the environmental evaluation, the regulating, provisioning, and cultural services were calculated and further complimented by a biodiversity assessment and likely cost of replacing affected habitats. All values were calculated and used for the estimation of the rail line impact.

In summary, the assessment of the natural capital for the three routes provides public authorities with a detailed overview of the losses and gains likely to occur through rail line development. This tool aims to assist in the rail line infrastructure decision-making process providing a means for attributing financial values to natural assets.

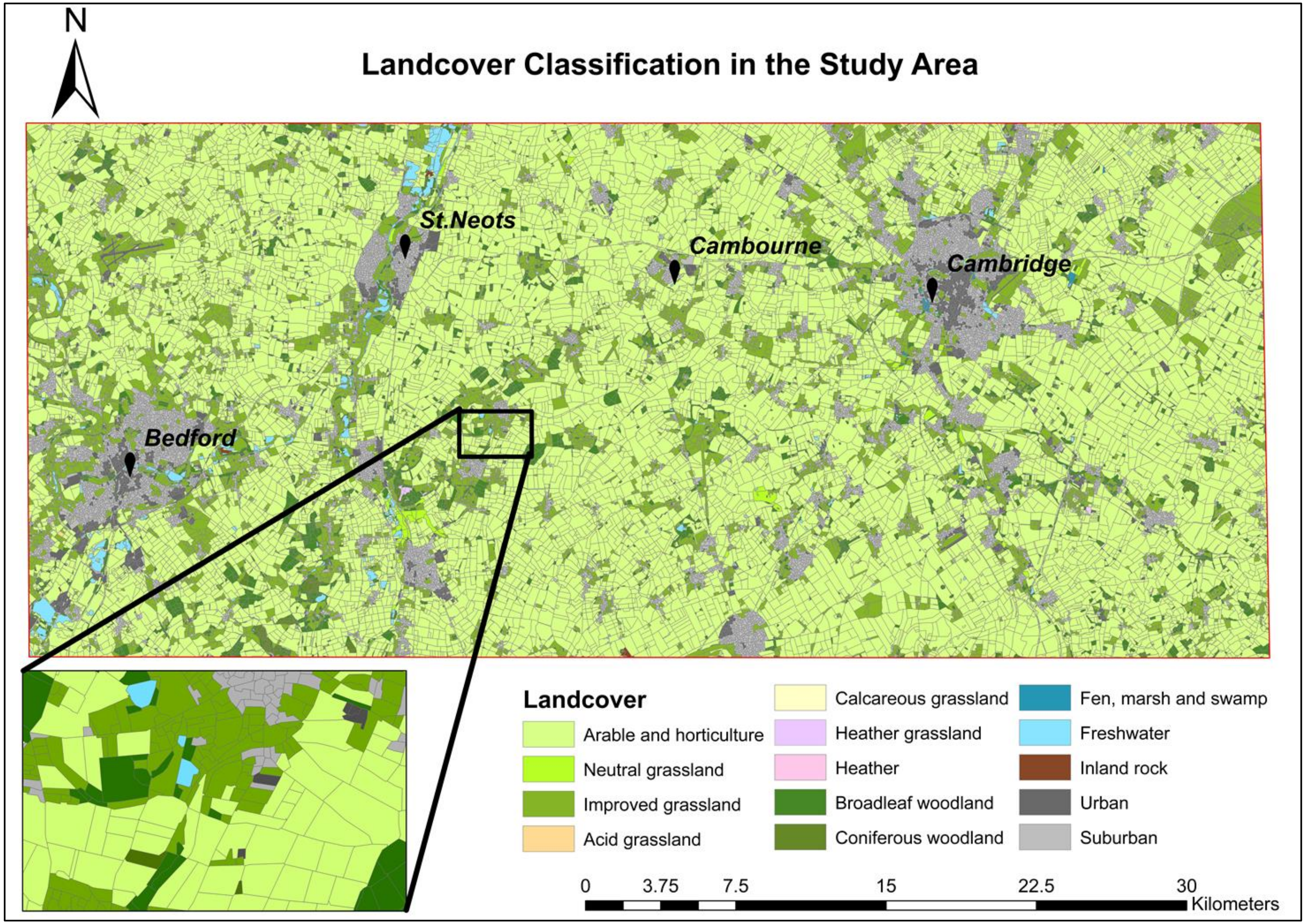

Figure 2-2: General view of the study area land cover.

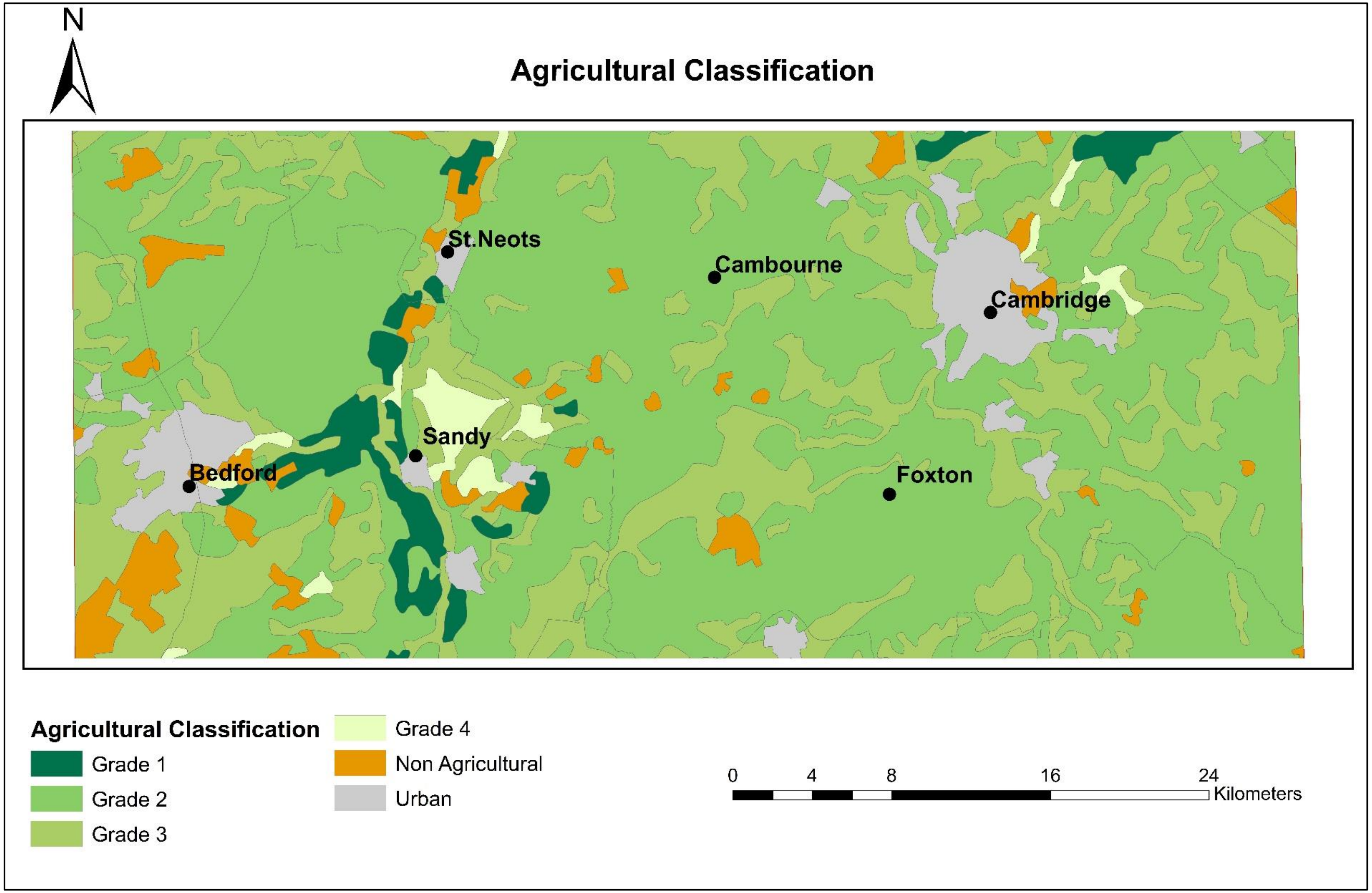

Figure 2-3: Agricultural Land Classification of the area.

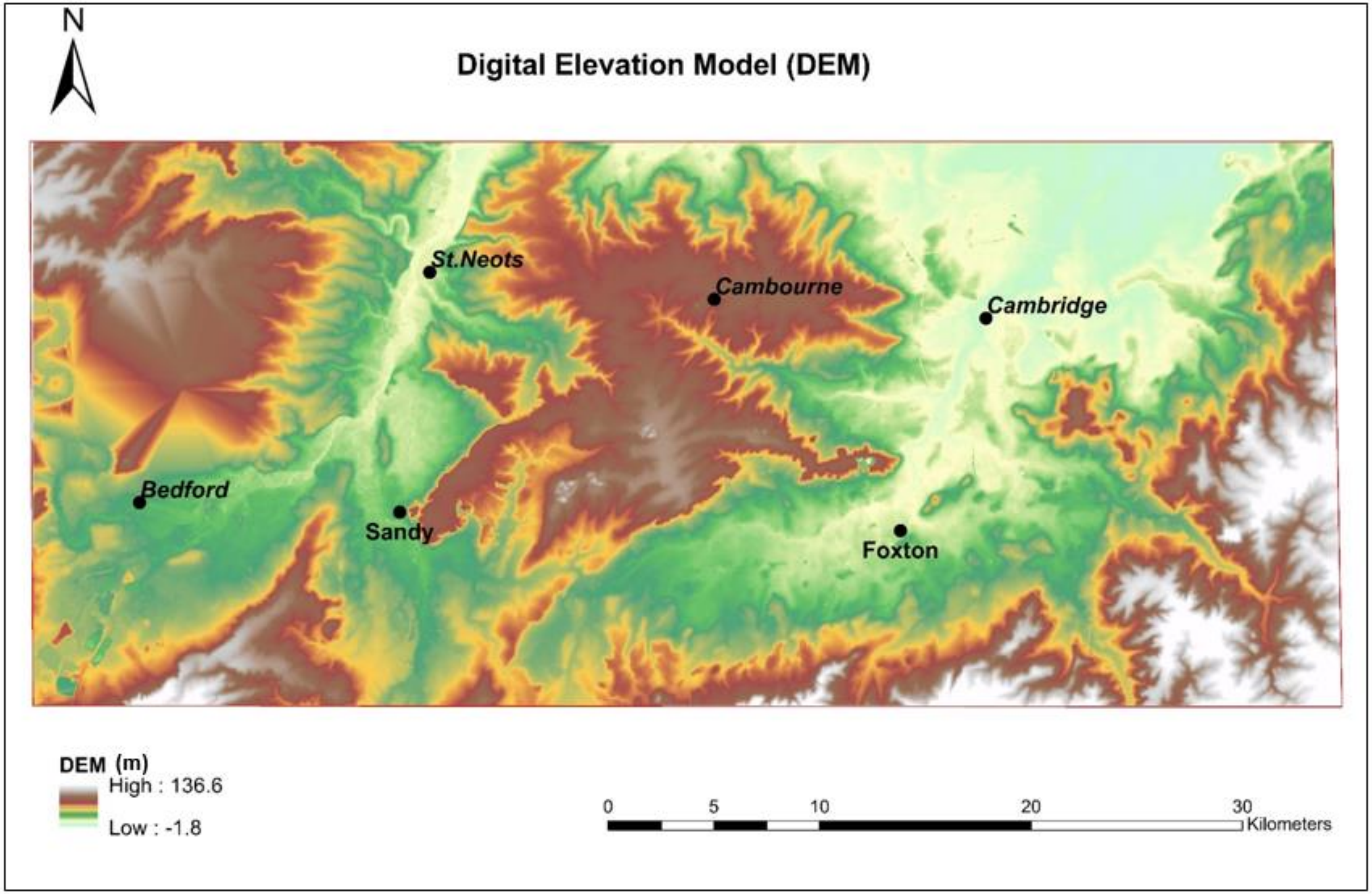

Figure 2-4: DEM that shows the elevation of the area in (m).

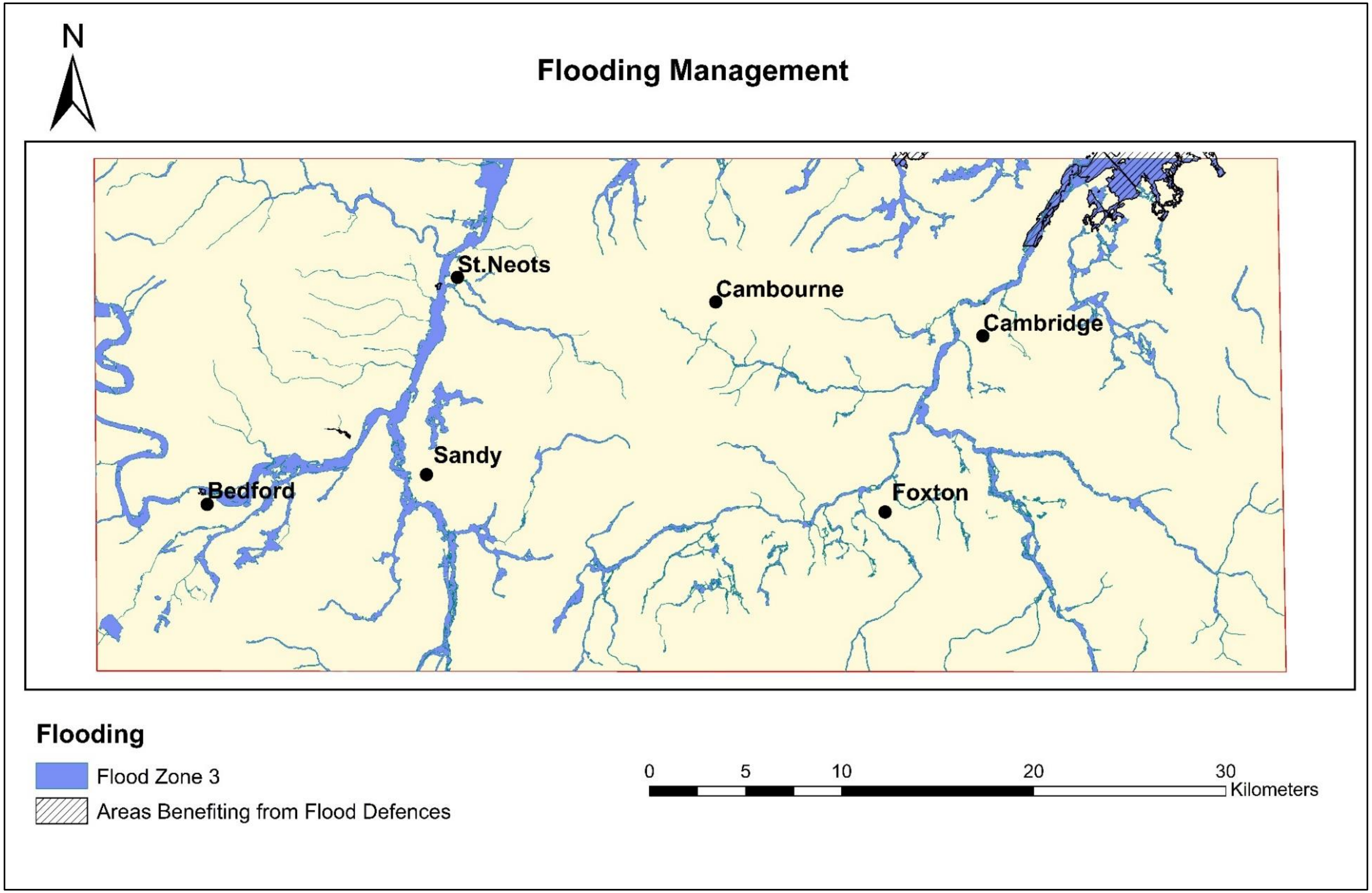

Figure 2-5 : Flooding areas between Bedford and Cambridge.

3 Map Creation

Map creation was an important part of the project, as it was helpful to identify the boundaries of the study area, discover and evaluate the locations that might be important for the project and for the selection of the routes of the rail line.

As the project was focussed around site selection for transportation routes, in particular the future rail line that will connect Bedford to Cambridge, the study area boundaries were chosen to cover most of the Bedford and Cambridge region. Facilities such as existing train stations and historic rail lines were focused upon with the idea that they could assist in connecting the two settlements.

To assist in selecting possible routes for the rail line, different map sources were used in the route selection process; these maps are shown in Table 3-1:

Table 3-1 : Maps types used in data creation and route selection.

Map name	Source	Scale	Format	Data availability
Land cover	Centre for Ecology and Hydrology	1:2500	Vector	Not open source
Buildings	Ordnance Survey (via Digimap)	1:10,000	Vector	Not open source
Landranger	Ordnance Survey (via Digimap)	1:25,000	Raster	Not open source
Flooding	Environment Agency	Not Available	Vector	Open source
Roads	Highways England	Not Available	Vector	Open source
Rail	Network Rail	Not Available	Vector	Open source
Agricultural Land Classification	Natural England (DEFRA)	1:250,000	Vector	Open source
Digital Elevation Model (DEM)	Ordnance Survey (via Digimap)	50 m	Raster	Not open source
Soils	LandIS (Cranfield University)	1:250,000	Vector	Not open source
Habitat	Natural England	Not Available	Online	-

All maps were downloaded and processed using different mapping tools such as ArcMap and Google Earth. The maps were published on ArcGIS Online in order to provide improved accessibility to the project participants. Some maps were created to locate points of interest in the study area in order to visit these points and assess them.

The choice for the location of the Northern Routte was made after studying the map sources mentioned in Table 3-1. The route was based on historic and existing rail lines, tunnels and bridges and topography with the aim to provide urban and rural areas such as Cambourne with improved transportation infrastructure. For route selection, two of the routes were based on prior proposed routes, one being from the 5th Studio spatial design agency, and the other, from EWR. These two routes were digitized and added to the map Figure 3-1, the third route was chosen by the Cranfield project team.

After the route selection, and for more specific assessments, maps were created for each different land cover classification within one mile of each route, in order to focus on the potentially impacted areas, and provide a detailed evaluation for each land cover including woodland, wetland, grassland and agricultural land. One mile was selected in order to allow modification of the alignment of the route, if necessary, in relation to natural assets, dwellings, topography, water courses and existing infrastructure. A greater distance could have been selected, however, undertaking natural capital accounting over a greater distance would involve a far lengthier process and was not feasible based on the duration of the project. Finally, a map with the exact area of each land cover crossed by each route was presented. This was based on the decision to attribute a 22-metre width for the rail line. Subsequently it became possible to calculate the exact loss of each land cover. A map of buildings within 30 metres, 45 metres, 60 metres and 75 metres to each route was created, to reflect and calculate the assumed compensation schemes. This map was created to establish the number of buildings within specific distances of each route; further maps were created to present the siting of tunnels, bridges and noise barriers.

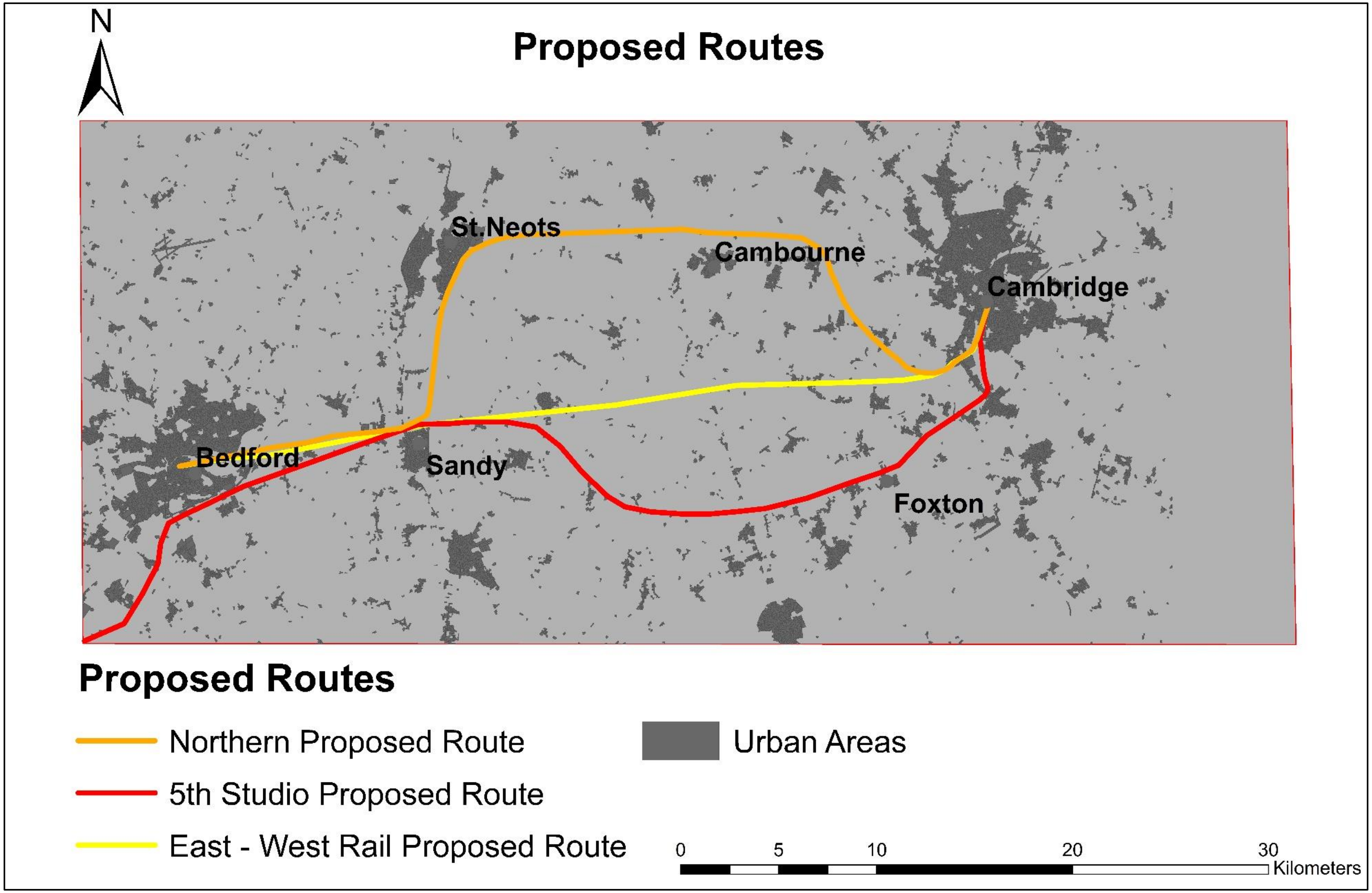

Figure 3-1 : Proposed routes for the ‘Central Section’ of the EWR route.

4 Route Specification

To specifically assess each route's impacts on natural capital, a focus has been particularly addressed on areas crossed by the suggested routes. After a general valuation, to differentiate benefits of various land covers, contrasts have been highlighted within those land covers. For instance, a recently-planted wood will not have the same biodiversity level as an ancient one, and grade 1 agricultural land might be costlier to lose than grade 4. A Geographical Information System was used to calculate area of disturbance by individual routes.

Environmental considerations are not the sole debate for decision-makers, hence the inclusion of non-natural facts which have been assumed and underlined, to balance the study and represent the bigger variety of factors at stake in the overall proposal.

4.1 Infrastructure Site Selection

A natural capital approach has been at the heart of this project, particularly focussing on the value of ecosystems goods and services and the benefits and disbenefits that occur when subjected to development. Whilst the project has focused on natural capital, other factors inevitably are responsible for route selection. Primarily, the Cranfield project team has focused on avoidance of SSSIs, LNRs, Biodiversity Action Plan (BAP) Priority Habitats and WT sites. However, this has not been entirely possible and due consideration has been applied where required.

When undertaking the route selection process, challenges became apparent, with a need to find solutions through the use of software and tools. The route suggested by the Cranfield project team has considered many factors, aiming to alleviate constraints faced by the proposed routes by EWR and 5th Studio. Evaluating both propositions enabled an understanding of the logic involved with site selection, alongside opportunities and constraints.

Avoidance of unnecessary blight, a key focus in the planning phase of this project, was attained through utilisation of existing rail line infrastructure. The historic 'Varsity Line', currently National Cycle Route 51, presented the obvious opportunity for avoidance of both construction blight and land acquisition, not to mention the benefit of existing bridges and foundations.

Further, the assumption has been made that the East Coast Main Line (ECML) provides a viable option for rail line interlinkage. This direct linkage would benefit Bedford, Sandy, St Neots, Cambourne, and Cambridge amongst others. The opportunity is presented for cost-reduction and improved settlement connectivity.

The speed of installation is considered, with the impending development of HS2 playing a key role in the thought processes. Due to the likely intersection of HS2 and EWR near the village of Calvert, completion of the 'Western Section' of East–West Rail is critical. The approach, as provided in the brief, is to utilise the historic 'Varsity Line', thereby, reducing unnecessary blight and accelerating infrastructure construction. This theory also presents itself as the most suitable way of avoiding blight and land acquisition for the 'Central Section' of the East–West Rail line.

DEMs enabled visualisation of potential topographical constraints and opportunities. Assessment was made through field observations and consideration of the use of tunnels (bored and cut and cover), landscape engineering embankments, sunken corridors and causeways proved insightful.

Improving transportation linkage, with particular consideration to future housing development within Bedfordshire, Buckinghamshire, Cambridgeshire and Hertfordshire, was a priority factor when assessing routes. Evidently, 5th Studio's main focus was on future housing development, particularly towards the south west of Cambridge. Bassingbourn already has access to rail infrastructure at Royston and the A1 at Letchworth proving to be an ideal location. Similarly, the abundance of land between Cambourne and Peterborough presents an option for expansion, albeit further from London.

Populations were assessed, primarily to assess the likelihood of disturbance. The data gathered is useful for assessing suitable locations for installing noise barriers and green belts, along with understanding the locality of the beneficiaries to the proposed rail infrastructure.

Construction costs have not been the focus of this project. Nevertheless, attention to such costs is provided and enlightens the assessors with respect to the opportunities that are presented. The route proposed by EWR provides the shortest commuter time and the lowest carbon footprint. However, the loss of habitat and the ecological mitigation required in relation to this route is likely to be substantial.

Interestingly, the approach by 5th Studio considered natural capital, particularly in relation to priority habitat areas as well as the utilisation of existing lines and stations, which provide the basic infrastructure needed for settlement establishment.

4.2 Opportunities and Constraints

The growth of the Oxford-Cambridge arc, also referred to as the ‘Oxbridge Corridor’, as well as London’s expansion, is not sustainable without public investment in rail and road infrastructure (Highways England, 2016).

The need for improved transport connection within the arc is evident due to the difficulty in commuting between Oxford and Cambridge. With the current rail infrastructure, a train journey takes 2 hours 29 minutes (Trainline.com, 2018), whilst a bus or coach journey is a duration of 3 hours 40 minutes (Megabus, 2018; Stagecoach, 2018). Additionally, traffic congestion particularly around Buckingham and the lack of a ring road around Milton Keynes results in a direct route through the entire city via the A421. Therefore, the use of private transport is restricted and impacted through relatively slow commutes between settlements.

Consequently, encouraging the use of public transport could be significant in terms of reducing the number of cars commuting from the cities of Cambridge and Oxford and their satellite settlements. Moreover, local economic benefits to rural towns can be gained in the form of increasing populations and business opportunities leading to new jobs and improved infrastructure such as libraries, restaurants, shopping facilities, inter-city corridors and leisure centres.

The development of new towns, to act as satellite settlements to the cities, of Cambridge, Oxford and London can be planned to work synergistically with the environment. The implementation of wet woodlands for flood alleviation, urban green infrastructure for noise attenuation, wetlands and meadows for biodiversity and parklands for recreation will provide a desirable environment which is tranquil and influential to future housing development. Additionally, bioengineering solutions can be tailored to meet the requirements for developing on floodplains through the use of sustainable urban drainage systems (SUDS), as well as the lessening of noise emissions through the use of green belts and green sound barriers which in turn aid with carbon capture through vegetation sequestration. Further information can be sought in Appendices B and C.

However, public opposition has been observed from the inhabitants of Bedford and Moulsoe by the Cranfield project team. Negotiations with landowners and investors unavoidably increase construction delays, thus, indicating a reason as to why construction footprints or conceptual designs are currently unavailable from Network Rail.

4.3 Logistics and Economics

The collaboration of landowners, conservation organisations, and governmental advisors is essential for managing an infrastructure project of this scale. Natural capital' is built on the ecosystem goods and services that are provided from an area. However, attributing a financial value to each and every service is a complex process, in particular, monetising of biodiversity. Therefore, encouragement is directed towards the avoidance of infrastructure development through species-rich sites where conservation ecology takes priority.

This is not to say that gains cannot be achieved through landscape restoration and remediation. Such remediation can gain revenue through infrastructure development, as there will certainly be habitat loss and the need for ecological mitigation. The synergy of new biodiversity and recreational hot spots can be observed at Graftham Water, Huntingdonshire.

A key point of the installation of this line is to provide an alternate means of transport that avoids going into central London for both passengers and freight services (Network Rail, 2018). Whilst this project has not focussed on the benefits and dis-benefits of freight services, the factors involved are similar. The length of the route, a locomotive's model and efficiency, and the speed at which it travels are vital in understanding the environmental impact.

Figures that can be presented include the number of passengers expected to be transported, estimations of a reduction in car journeys and an estimation of the mass of vehicle pollution that could be offset based on a reduction in the number of cars commuting between Oxford and Cambridge and anywhere in between.

4.4 Routes Details

EWR, 5th Studio and the Northern Route will cover the distance between Bedford and Cambridge and were designed following different criteria. While the EWR is the straightest option, the Northern Route tends to cover the northern part of the study area. Consequently, the length and journey time will be different. As mentioned before, when designing the routes, the use of existing rail lines was attempted with the purpose of minimising the distance to build as well as the construction cost and the environmental impact. Table 4-1 summarises the length of the routes, the distance to build and the journey time assuming a train speed of 100mph without any stops. (Railfuture, 2014),

Table 4-1 : Route length and journey time specification.

Route	Length (km)	Length to build (km)	Journey time (min)
EWR	45	42	17
Northern Route	54	44	21
5th Studio	55	40	21

4.4.1 Journey Time

According to Railfuture (2014), trains between Bedford and Cambridge will run at a speed varying from 100 mph to 125 mph. Due to stops, speed reductions and restrictions in urban areas, the 100 mph will be taken as an average to compare the different route options. With a distance of less than 35 miles, people may commute from Bedford to Cambridge in less than 25 minutes by rail. As Table 4-2 shows, the new rail route would halve the average road travel time as well as be more than five times quicker than today's train journeys (Appendix A).

Table 4-2 : Estimated travel time from Bedford to Cambridge (35 miles) with different transport options.

By car (minutes)	By public bus (minutes)	By train (existing rail) (minutes)	By train (future rail) (minutes)
51	60	137	**< 25**

4.4.2 Engineering Constructions

At a glance, the rail tracks will have a width of 22 m in a non-urban area, 15 m in urban areas and be much wider in the vicinity of a potential tunnel. Some engineering constructions were evaluated in order to make possible the development of the routes.

4.4.2.1 Tunnels

Trains cannot run on a gradient superior to 1.25%, therefore, two tunnels of 2.7 and 2.3km will have to be built on the 5th Studio route and one tunnel of 2.8km on the EWR route. The location of such tunnels can be seen in Figure 4-1. It would add respectively £329m and £187m to the project costs, with a price of £66m/km given by the infrastructure rate comparison from the HS2 model of risks and costs (HS2, 2012) Appendix B provides greater detail on the use of tunnels within the study area. No tunnels are required on the Northern Route.

4.4.2.2 Bridges

Four bridges, each with an average length of 80 m would be needed on the Northern Route costing approximately £17m. One bridge nearing 95m would be required on the EWR route, with a cost of £5m (Appendix B). Figure 4-2 shows the proposed bridge locations.

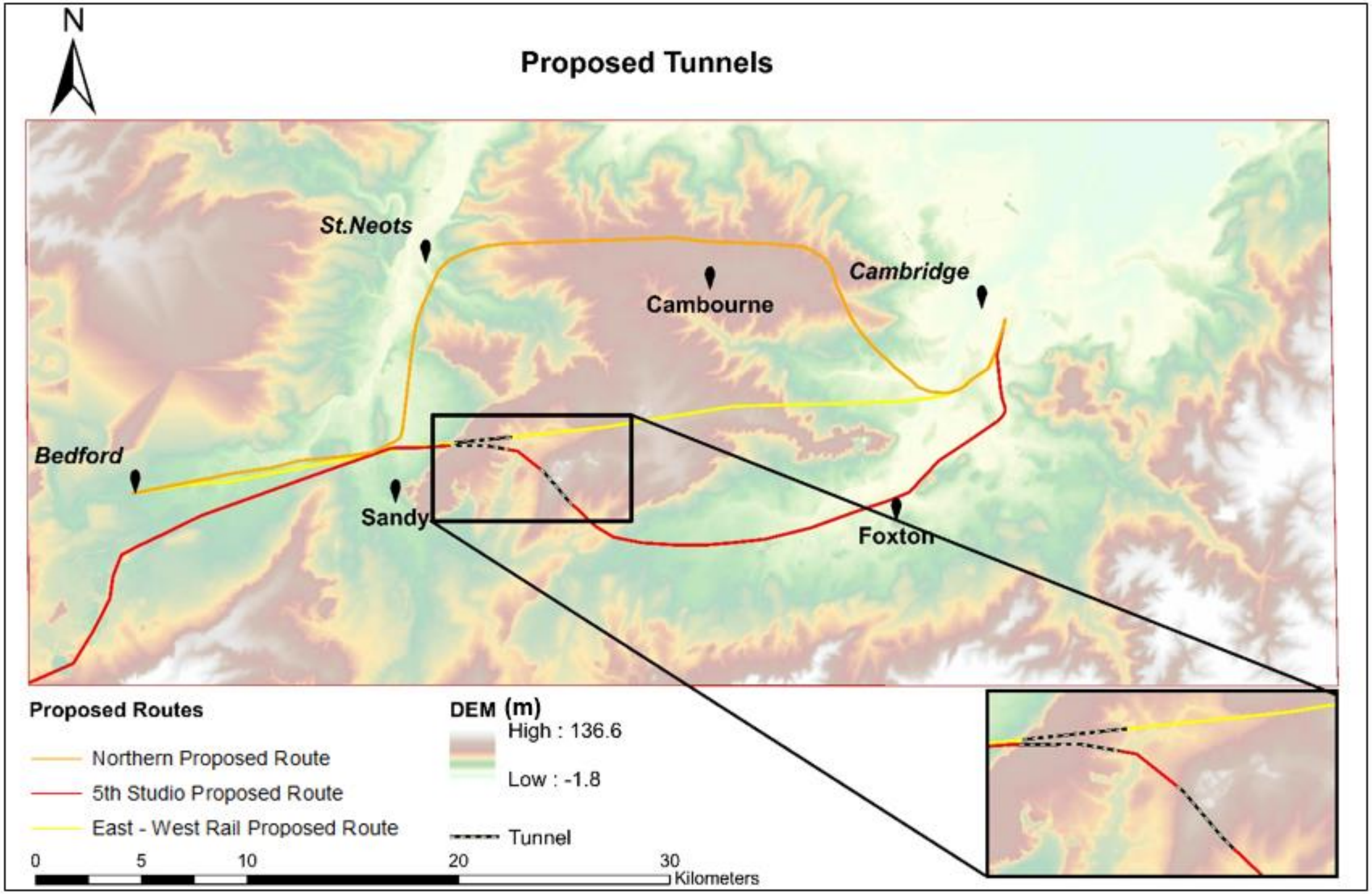

Figure 4-1: Tunnels placement.

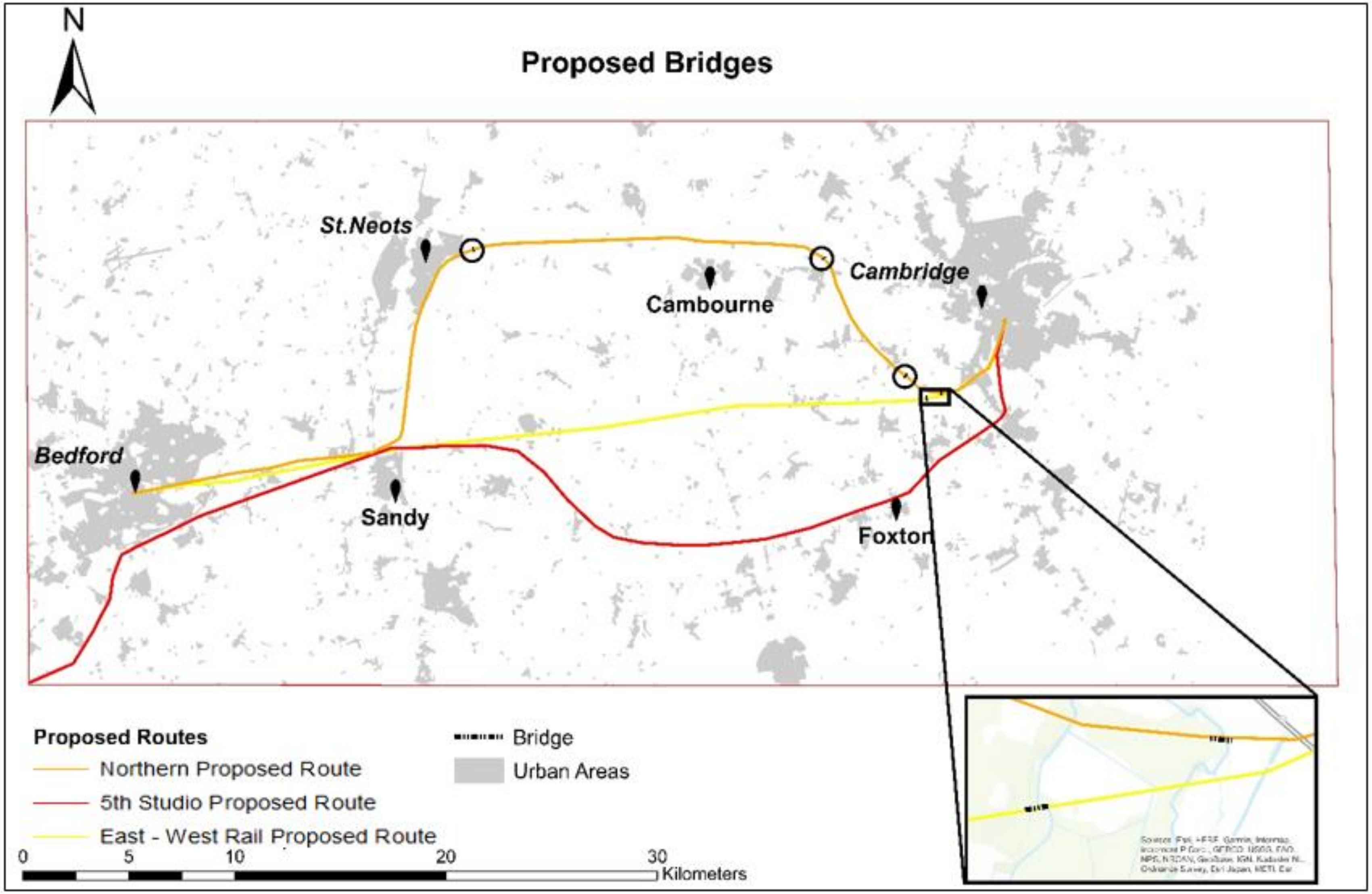

Figure 4-2: Bridges placement.

4.4.2.3 Noise Barriers

Consideration of noise emissions from running trains leads to the necessary provision of mitigation. Such acoustic impact on human welfare inevitably gives cause for concern, lending to a thought process for potential ways to alleviate such issues. Running trains emit around 100 decibels (dB), therefore, areas, especially populated towns and villages, within less than one kilometre of rail lines would benefit from the installation of noise barriers (Appendix C).

Based on estimations by Dobson and Ryan (2000), the following suggestions are presented. A 3m-high solid barrier is recommended to reduce noise emissions by 15dB. Trees could be planted to form a 10m-wide green belt for mitigation of a further 5dB. An additional 3dB might be lost by the distance from the point source. Hence, at the edge of a 10m-wide green belt which is about 26m from the centre of the track, the noise level would reduce to 77dB. The barriers of 3m in height would cost £1,174/m and planting of a green belt alongside the tracks would equate to approximately £7,888/ha (Environment Agency, 2015).

Where tracks would be within one kilometer of a settlement, that is greater than 1,000 inhabitants, the Cranfield project team recommends the installation of artificial noise barriers. Further information can be found in Appendix C. Their length and costs are accounted for in Table 4-3 whilst their allocated locations are demonstrated in Figure 4-3.

Table 4-3 : Routes cost.

Route	Length (km)	Cost (£m)
EWR	11.93	28
Northern Route	11.33	27
5th Studio	9.62	23

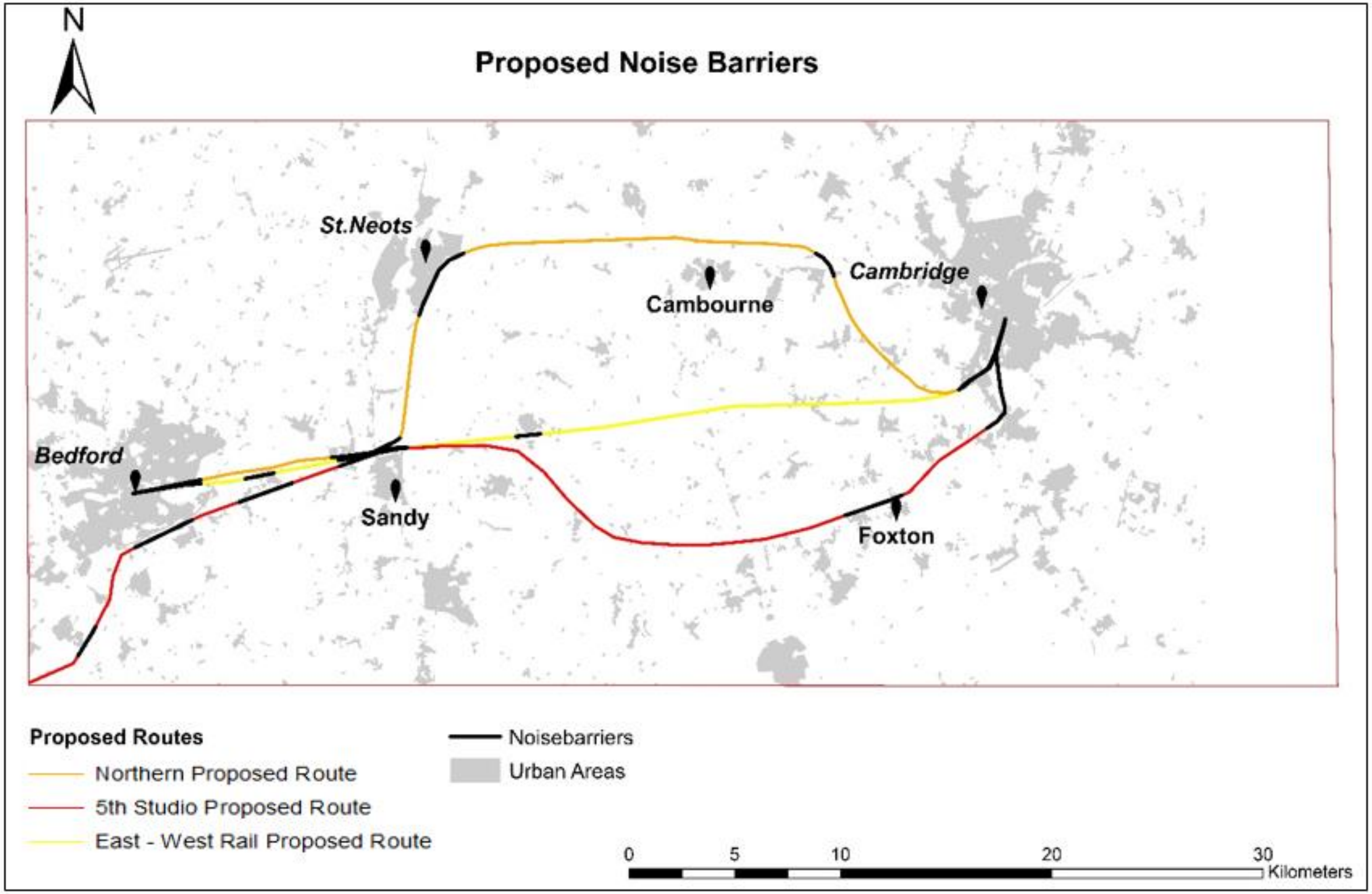

Figure 4-3: Noise barriers placement.

4.4.2.4 Land Owner Compensation

The route will cross existing housing areas hence the need for land owner compensation. On the one hand, following the HS2 report, it was assumed for this project that houses within a distance of 30 m of the rail line should be bought back at 110% of their value. On the other hand, compensative payments of £22,500 will be given to properties within 45 meters, £15,000 within 60 metres and £7,500 within 75 meters of the rail line.

However, when the train is circulating on existing rails or underground then properties are not exposed to new emissions, though consideration should be addressed to the increased likelihood of disruption. Tunnels and the use of existing rail lines would reduce the number of buildings requiring compensation and thereby their utilisation is recommended where suitable.

The number of buildings situated around the different options, as well as the costs potentially involved in their removal or compensation is presented in Table 4-4. The detailed calculations can be found in Appendix A. Moreover, Figures 4-4 and 4-5 show the buildings across the routes.

Table 4-4 : Landowner compensation values along individual routes.

	Buildings within 30m distance	Buildings within 45m distance	Buildings within 60m distance	Buildings within 75m distance
EWR	174	59	55	52
Compensation (£)	62,846,956	1,327,500	825,000	390,000
Northern Route	113	43	50	49
Compensation (£)	40,814,402	967,500	750,000	367,500
5th Studio	36	17	19	13
Compensation (£)	13,002,818	382,500	285,000	97,500

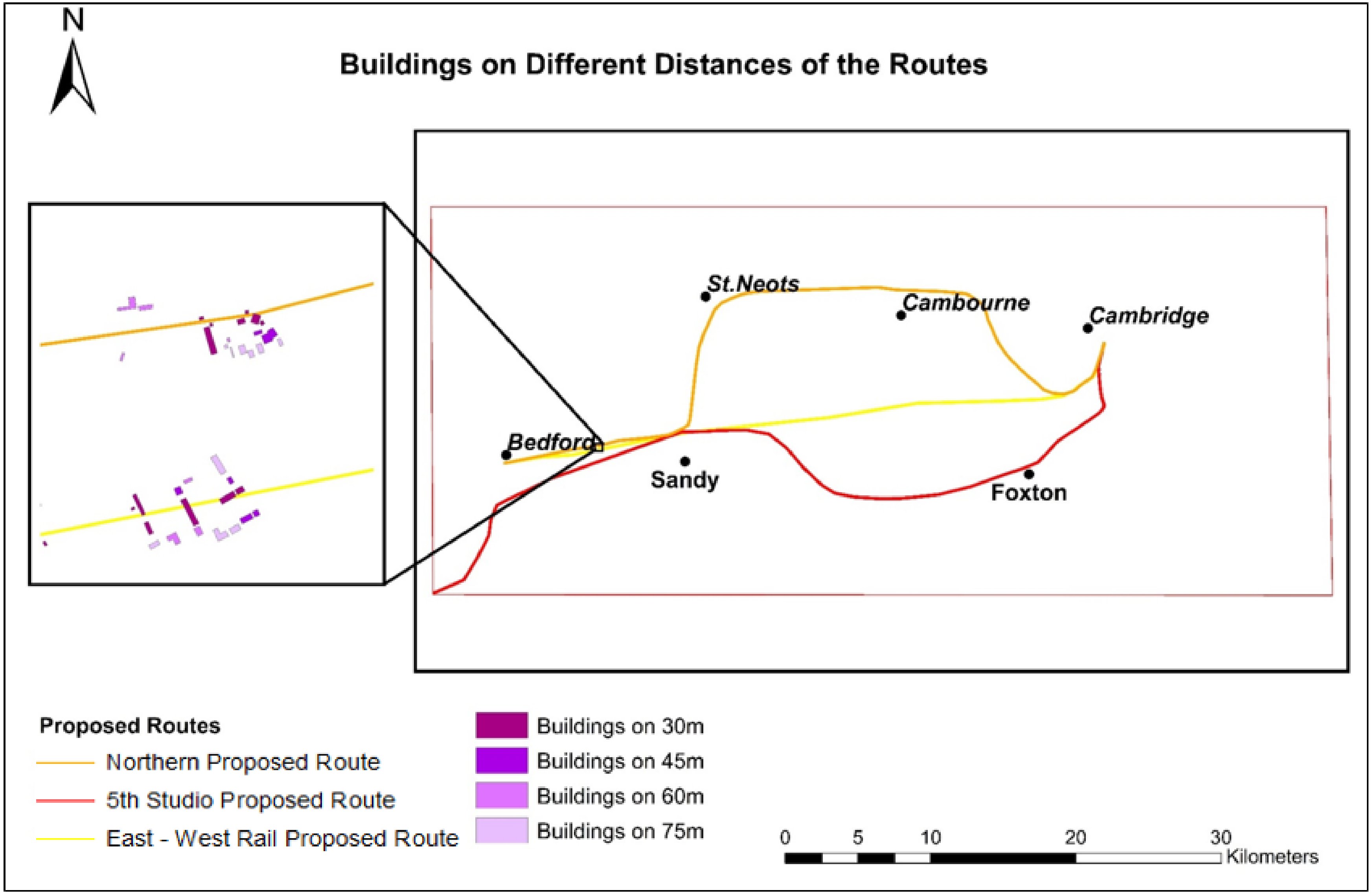

Figure 4-4: Buildings on Different Distances of the road.

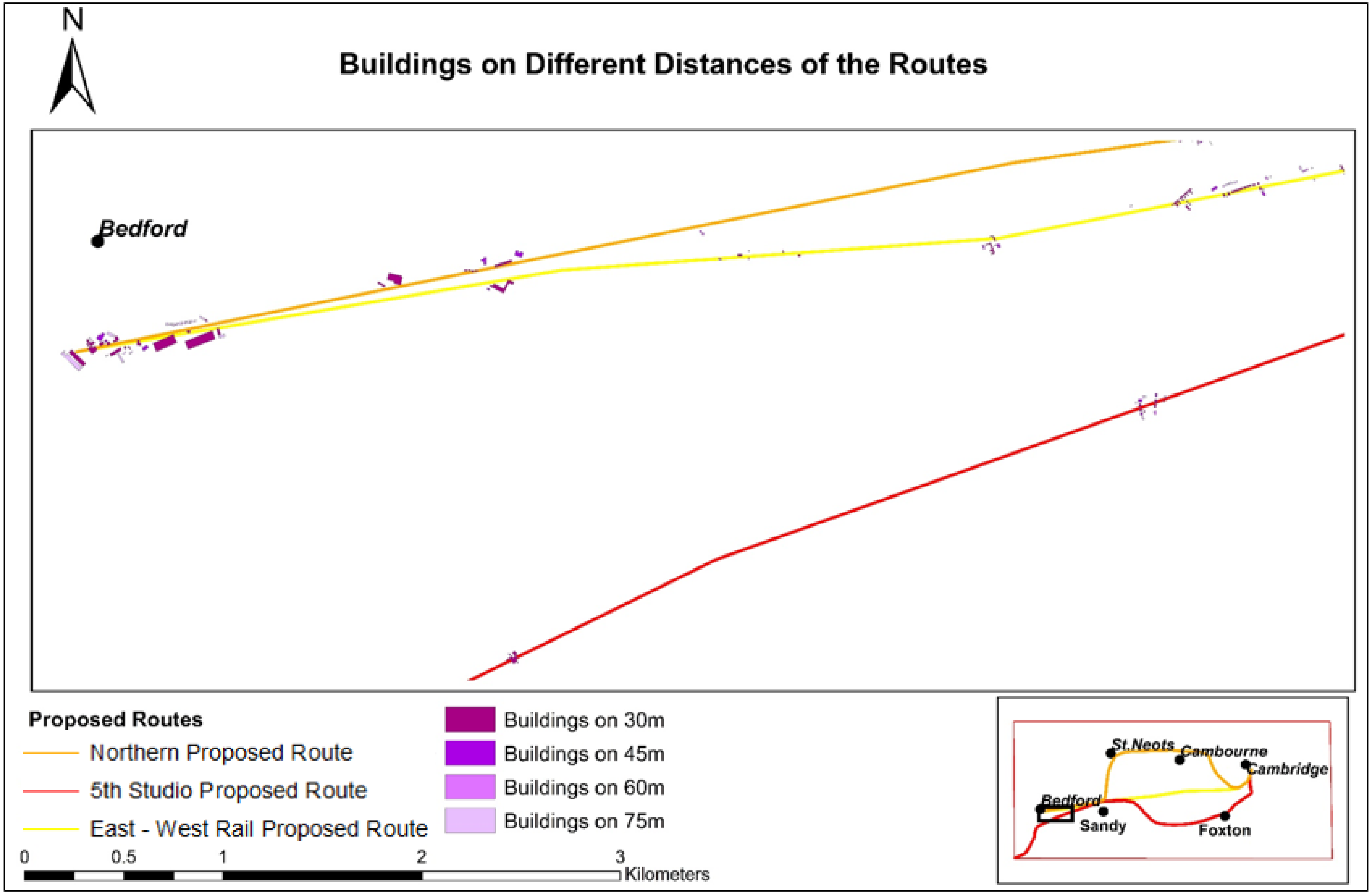

Figure 4-5: Cross section of buildings on different distances.

4.4.3 Non-Natural Costs and Considerations

Displayed in Figure 4-6 is the relative importance of each routes specifications on a scale of 100%. Consideration of journey time, distance to build, tunnel lengths, noise barrier lengths, bridge lengths and importance of buildings nearby have been expressed as a percentage of the sum of the three routes, to allow the creation of a graph showing all the considerations previously listed.

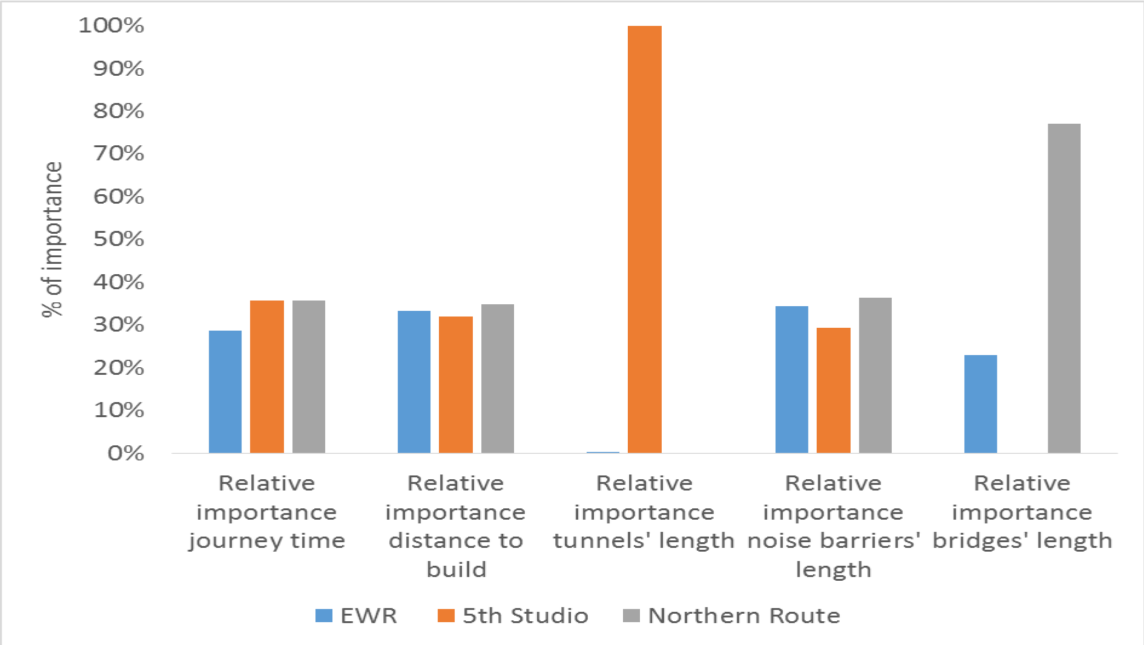

Figure 4-6: Relative importance of non-natural considerations per route option (0-100%).

Directly related to the distance between Bedford and Cambridge, the EWR option would be the quickest one. However, due to the use of existing rails, the distance of rail to build would be rather similar between the three options. The EWR route and the 5th Studio option would need respectively one and two tunnels. These, with a cost of £66m/km, would drastically impact the engineering costs. Indeed, despite its length of tunnel, the Cranfield project team proposal would stand as the cheapest option whereas the 5th Studio report highlighted an option with the smallest length of noise barriers, bridges and the smallest number of compensated householders, but it is more expensive than the two others as shown in Figure 4-7.

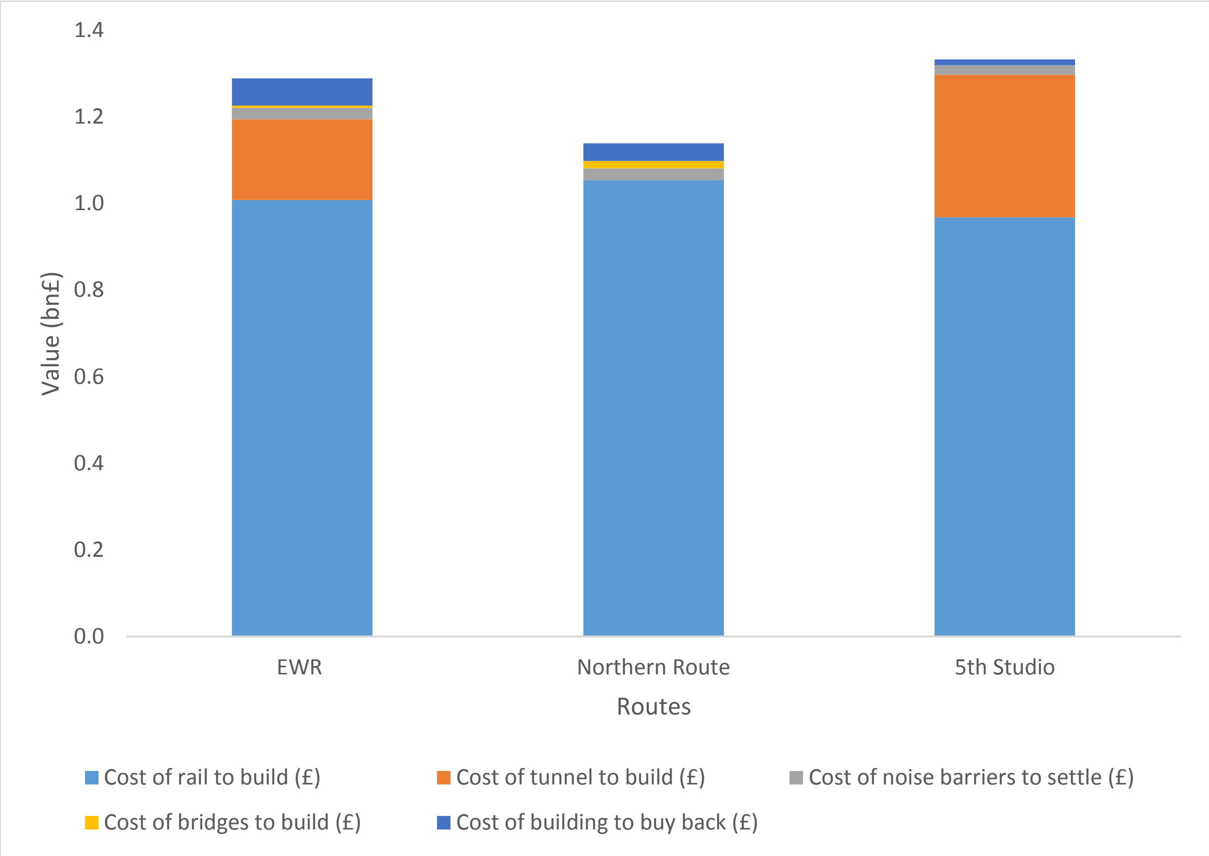

Figure 4-7: Detailed engineering cost (in £) associated with each route option.

To sum up, the average cost of this project will rise at £24m/km, reaching £66m/km for tunnelled distances. A two-track single span rail bridge, rising from 0 to 10m would cost £2,346/m². Table 4-5 summarise the construction cost associated with each route.

Table 4-5 : Engineering requirement summary for each route.

Non-natural criteria	EWR	Northern Route	5th studio
Distance Bedford-Cambridge (km)	44	54	55
Journey Time Bedford-Cambridge (min, 100 mph)	16	20	20
Rail length to build (km)	42	44	40
Cost of rail to build (£)	1,007,976,000	1,053,600,000	967,776,000
Number of tunnels	1	0	2
Tunnels length (km)	3	0	4,989
Cost of tunnel to build (£)	186,516,143	0	329,270,885
Noise barriers needed (km)	11	12	10
Cost of noise barriers to settle (£)	26,609,884	28,011,640	22,587,760
Number of bridges (width 22m)	1	4	0
Bridges length (km)	0.10	0.33	0
Cost of bridges to build (£)	5,006,364	16,825,512	0
Buildings within 30m	174	113	36
Cost of building to buy back (£)	62,846,956	40,814,402	13,002,818
Total cost (£)	**1,288,955,346**	**1,139,251,554**	**1,332,637,463**

5 Environmental Valuation

Aside from initial route sketches, in an evolving process, a general environmental valuation has been conducted. This valuation followed an ecosystem approach to evaluate the goods and services associated with a range of different land covers. An intensive literature review seeking for mainly UK figures has furnished enough material to build comparison tables. These tables rank different types of services to give first ideas of the importance of each land use. They contain financial ecosystem services values per hectare, levelled at the 2030 horizon. Many sources were investigated to produce a general valuation of the different land covers studied including: UK-NEA, Department for Business Energy & Industrial Strategy (2018), Environment Agency (2015), DEFRA (2012), Ordnance Survey (2018), University of Exeter (2018), Scottish Natural Heritage (2007), UK Soil Observatory (2017), Woodland Trust (2011), Sandwood Enterprise (2013), European Commission, (2015) and Natural England (2014a, 2014b). However, due to the number and variety of sources, and the impossibility of drawing relevant conclusions from such a mix of figures, it was decided to choose similar methods for all land covers. The number of sources is mitigated, to a certain degree, by this process harmony. The detail of the data analysis is presented in Appendices G and H.

5.1 Environmental Services Evaluation for the Areas' Land Cover

5.1.1 Cultural Values

The cultural services of ecosystems are defined as the environmental environments from which people obtain cultural goods and benefits. Examples of environmental environments through which people interact with nature are many, and include recreational areas in green and blue spaces and the landscapes of urban and rural areas (Church *et al.*, 2011).

All the cultural values have been taken from the same source, being the Outdoor Recreation Valuation (ORVal) tool, created by the University of Exeter, in partnership with DEFRA. The values and the estimates of the visits calculated by ORVal for the green spaces, come from the predictions of a model of recreational demand for England. It should be noted that they are not real measures but are indicative of a typical green space.

Although ORVal encompasses important characteristics of green spaces, it does not count the unique characteristics of each one (University of Exeter, 2018). Change in cultural values of specific places of the studied areas such as when grass, arable, bogs or woodlands were replaced by buildings have been noted and carefully controlled. This was achieved through specific alteration of changes in land use within the ORVal tool, enabling a basic estimation of the future scenario and the loss of cultural value that could occur as a result rail line construction. Outliers were excluded, because they were high and could be calculated errors within the model. The numbers presented below are the values that have been averaged from the ORVal database.

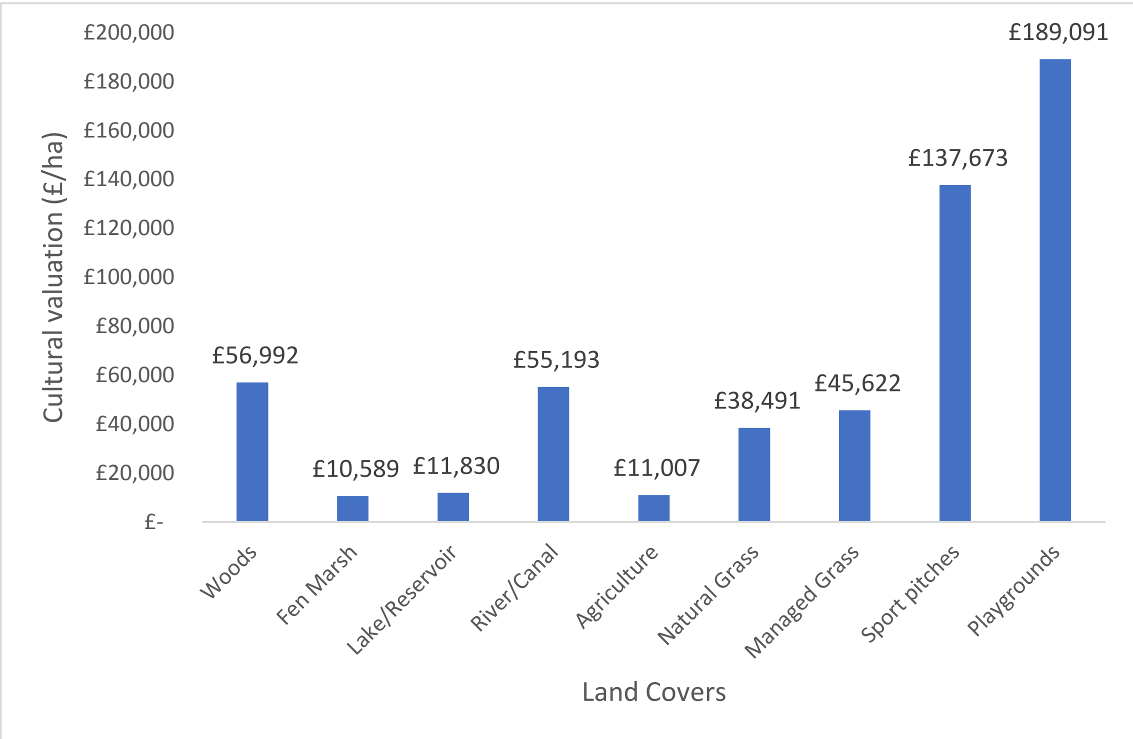

Figure 5-1 : Average of the cultural values of the different land covers in the studied area (£/ha).

The values in Figure 5-1 were chosen from a similar source and calculated by the same method. The values give an idea of the relative importance of land covers to inhabitants in the area. Therefore, artificial playgrounds and sports pitches have a very significant cultural value that comes before the natural assets that are forests and rivers. On the other hand, it has to be noted that wetlands, despite having a high cultural value, reach a low value in the study. This is because they were not numerous in the area.

5.1.2 Regulating Values

Climate regulation, maintenance of the quality of air and soil or pollinating crops are some of the “regulating services” provided by ecosystems. Those services are constituents of human well-being and are closely linked with the security and health of the population (Watson *et al.*, 2005; FAO, 2018).

Ecosystems can regulate climate by storing greenhouse gas (GHG) emissions, mainly carbon dioxide (CO_2). However, it is estimated that one-third of the GHG emissions are due to land-use conversion and soil cultivation (FAO, 2018). Consequently, due to the importance that ecosystems have in regulating GHG emissions, the contribution of each land cover, to climate regulation, was evaluated.

For that above mentioned purpose, the yearly carbon storage, as well as the total amount of sequestrated carbon, have been selected allowing an assessment of the regulation value of those land covers. Hence, fens or bogs would sequester approximately 279 t CO_2/ha (Natural England, 2010), whilst on average broadleaf woods could sequester 638 t CO_2/ha (Sandwood Enterprise, 2013). Moreover, 343 t CO_2/ha are sequestered by natural grasslands in comparison to 300 t CO_2/ha for improved and managed grasslands (UK Soil Observatory, 2017). However, lakes and rivers do not sequester carbon and there is great difficulty in attributing sequestration values to arable lands. Even more, arable lands emit an annual amount of 10 t CO_2/ha (Les *et al.*, 2011).

In order to estimate the cost involved with the carbon sequestration, the predicted average carbon value in 2030, estimated by UK government, was selected, providing a value of, £79.43 t CO_2 (Department for Business Energy & Industrial Strategy, 2018). This value was used for calculated the CO_2 sequestrated by each land cover within the area. Figure 5-2 summaries the results obtained.

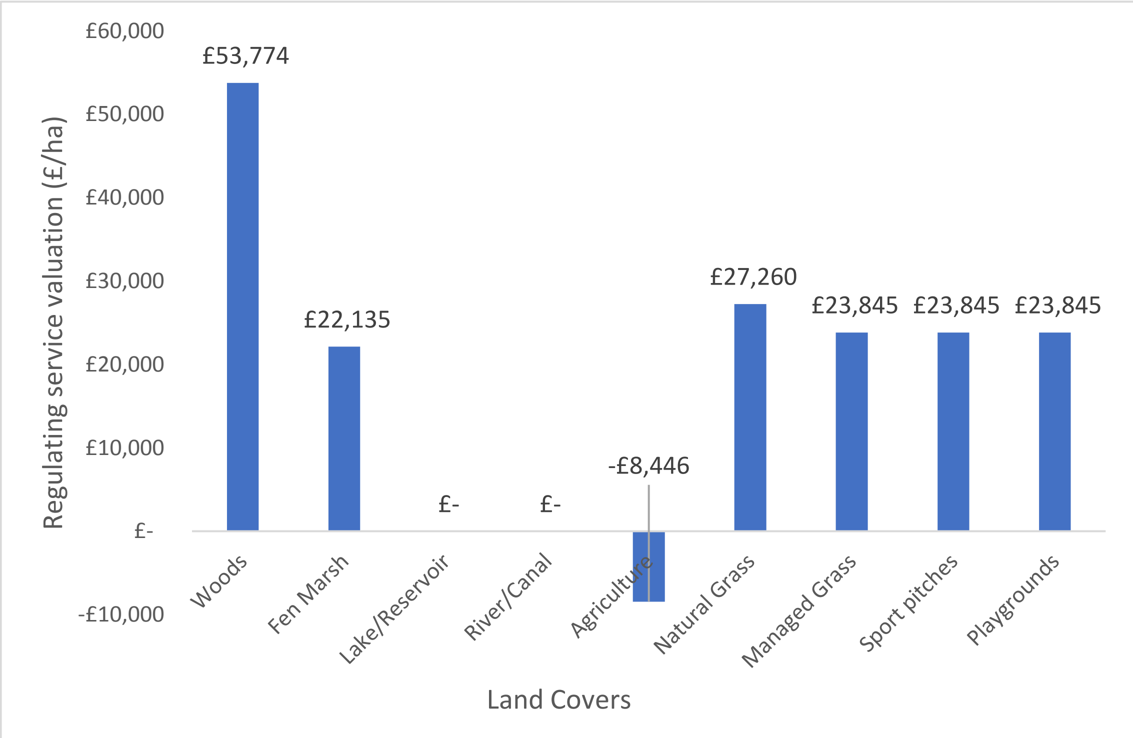

Figure 5-2: Carbon sequestration valuation of land covers with an average 2030 cost of £79.43/t CO2e.

According to the values obtained, the carbon sequestration value of woods is richer than any other land covers due to the extensive stores of carbon in vegetation and soil. Remaining land covers found throughout the area have relatively equal regulating service values, except for agricultural lands, which produce CO_2, due to activities hosted at their surface, such as agronomic management techniques. As a consequence, this regulation service is difficult to attribute and, in this instance, a negative value is obtained.

5.1.3 Provisioning Values

Provisioning services are those which are materialistic and benefit people and tradeable goods that are acquired from ecosystems, such as water, material and food. Most provisioning goods are traded as stocks in markets, and a certain percentage of provisioning services provide an income for rural communities that rely heavily on traditional land management practices such as agriculture, forestry and fishing (FAO, 2018).

When harvested in a sustainable way, non-ancient woods could provide an income of £120/ha/year, amounting to £1244/ha (Tinch *et al.*, 2010) when discounted at the horizon of 2030. Freshwater areas are much richer, bringing an average of £3,017/ha for commercial fishing and £3,163/ha for water supplies (Morris and Camino, 2011).

However, the most important provisioning ecosystems are agriculture and grasslands. Agricultural lands equate to a value of about £1,638ha/year, which could reach £16,980/ha at the 2030 horizon. This has been calculated based on the arable lands of Bedfordshire (calculated with AHDB prices per ton and the average yields per hectare). The arable lands are nearly equated by grasslands with their horizon value set to reach £16,206/ha (TEEB). Figure 5-3 sums up the provisioning values obtained.

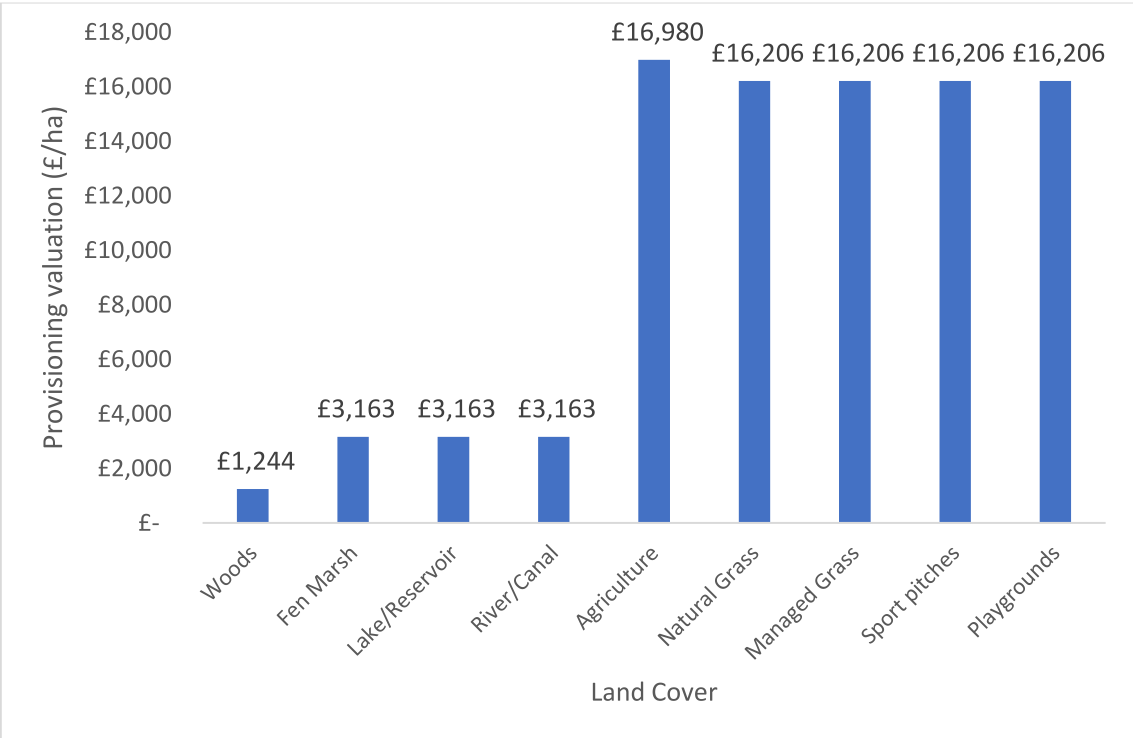

Figure 5-3 : Provisioning valuation of the different land covers within the area (£/ha).

5.1.4 Habitat Values

As a consequence of route development, the habitats of the area will be damaged. Therefore, necessary processes known as biodiversity offsetting can be undertaken and achieved through conservation activities. Such activities can assist in accounting for and suitably replacing biodiversity losses especially through appropriate compensation for losses (DEFRA, 2012). Offsetting methodologies compare the losses due to an impact, such as the rail line development, with net biodiversity gains being obtained through offsetting.

The methodology followed in this report is based on the HS2 and DEFRA metrics (DEFRA, 2012; HS2, 2015). The metric provided a measure of the overall biodiversity, its condition and the difficulty and duration of recreation. Table 5-1 provides an illustration of the metric system followed.

Table 5-1 : Summary of different biodiversity metric descriptions.

Distinctiveness	Condition	Habitat Recreation	Time to target	Biodiversity value (After impact)	Replacement ratio
Very high: 8	Good: 3	Remain:1	Remain: 1	24	1:01
Very high: 8	Good: 3	Easy: 0.9	10 years: 0.71	15.34	< 2: 1
High: 6	Medium: 2	Medium: 0.5	21 years: 0.52	3.12	< 8: 1
Poor: 2	Poor: 1	Hard: 0.1	>32years: 0.33	0.066	364:1

Source: (Natural England, 2016)

In order to obtain the offsetting ratio, the biodiversity units before and after the construction can be calculated with the multiplier summarised in Table 6-1. The biodiversity units could be calculated evaluating the distinctiveness and condition of the land. Firstly, according to the HS2 metric, distinctiveness could go from “very high” (8) to “poor” (2) for the baseline units, however, the replacement habitat could just reach a “high” (4) distinctiveness. Secondly, the condition of the area ranges from “good” (3) to “poor” (1). To calculate the biodiversity units needed for replacement, the ‘difficulty of habitat recreation’ and the ‘time needed to get the target condition’ should be calculated.

Usually, the biodiversity units after the impact are lower than those before it, consequently, more habitat units are needed. The ratio provides a means for calculating the required area needed to offset the loss of the original biodiversity units.

In other words, and following the values given in Table 6-1, land with very high distinctiveness (8) and good condition (3) will have a value of 24 before the impact occurs. If the land is replaced by a similar one, with a smaller distinctiveness (6), easy to recreate (0.9), reaching an average condition (2), after ten years (0.71); then the biodiversity units after the construction are 8. Consequently, approximately 3 times more area should be created to mitigate the biodiversity loss of the destroyed area. Appendix G contains a detailed assessment on the ratios utilised for this project.

The process mentioned above was used for woodland, wetland and grassland. The area of arable agricultural land within the area is substantial. Hence, the performing of valuation using the same procedure is not feasible within the time frame of this project Therefore, a global assumption was made, calculating the value of the habitats according to the size of the lands and their grade of classification.

Consequentially, the good condition (12) of uncultivated strips have been considered as the existing field biodiversity, and weighted with the poor one (4) representing the condition of a replacement field biodiversity at the start. Similarly good (6) and poor (2) conditions of cereal fields were compared. The difference between existing and replacement habitat riches have then been weighted with Bedfordshire percentage of crops (The Environment Bank, 2013).

The ratios reached for this project are listed in Table 5-2. Appendix G contains the assumptions made to obtain the values.

Table 5-2 : Replacement ratio for land covers in the area.

Land description	Replacement Ratio
Wood in an average condition (good distinctiveness)	20:1
Rich wetland in good condition	5:1
Natural grassland	4:1
Managed grassland (fertilised, mowed or cultivated)	3:1
Arable land	3:1

The Environment Agency (EA) have published costings for recreating different habitats (Environment Agency, 2015). Those values were modified to account for inflation and used to value financially the replacement cost per hectare. Figure 5-4 sums up the habitat valuation cost (£/ha) of the land cover within the study area.

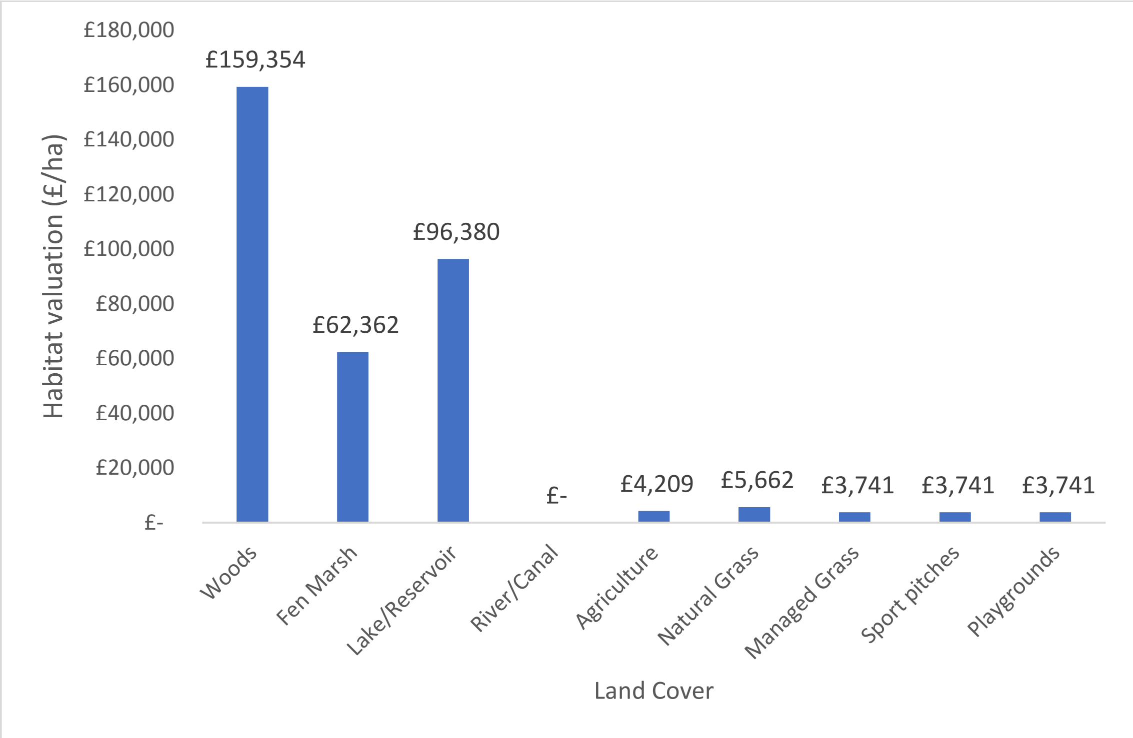

Figure 5-4 : Habitat valuation for the different land cover (£/ha).

As seen in Table 5-2, the replacement ratio is bigger in those land covers which are not subjected to intensive human intervention such as improved and managed grasslands where the use of fertiliser and mechanical equipment is a regular occurrence. Consequently, three main biodiversity financial values, woods, lakes and fens are highlighted. On the one hand, the importance of woods is simply explained by the significant replacement ratio calculated (a requirement of 20 ha planted for every hectare lost). On the other hand, lakes and fens, despite their replacement quotas being similar to grasslands, are justified by the substantial cost of recreating inland bodies (£23,854/ha) or marshes (£11,576/ha) in comparison to the relatively low costs of recreating dry grasslands (£1,403/ha). This figures have been derived for the values produced by the EA for land creation with the estimations being levelled at today's pound value (Environment Agency, 2015; Alioth Finance, 2017).

5.1.5 Ecosystem Services Values for the Study Area Land Cover

The most significant findings for different land covers are shown in Table 5-3. The financial values and the proportion of each one gathered are correspondingly attributed to each ecosystem service within specific land covers. These numbers are average values for the associated areas. They may vary from a diversity of factors used to create a specific assessment of land cover, which have been studied in Table 5-3 (and in the Appendix H) zone by zone.

Table 5-3 : Average values of ecosystem services for the study area land cover.

Land cover	Ecosystem services	Financial value	Total value	Proportion
Wood	Habitat	£159,354	£271,364	59%
	Cultural	£56,992		21%
	Provision	£1,244		0%
	Regulation	£53,774		20%
Arable	Habitat	£4,209	£23,730	18%
	Cultural	£11,007		46%
	Provision	£16,980		71%
	Regulation	-£8,446		-36%
Fen Marsh	Habitat	£62,362	£98,249	63%
	Cultural	£10,589		11%
	Provision	£3,163		3%
	Regulation	£22,135		23%
Lake/Reservoir	Habitat	£96,380	£111,373	87%
	Cultural	£11,830		11%
	Provision	£3,163		3%
	Regulation	£0		0%
Natural Grasslands	Habitat	£5,662	£87,619	6%
	Cultural	£38,491		44%
	Provision	£16,206		19%
	Regulation	£27,260		31%
Managed Grasslands	Habitat	£3,741	£89,414	4%
	Cultural	£45,622		51%
	Provision	£16,206		18%
	Regulation	£23,845		27%

As shown in Table 5-3, a typical wood of the area would be worth £271,364/ha, with biodiversity representing nearly 60% of this financial value and cultural and regulation services accounting for approximately 20% each.

On the other hand, a typical arable land of the area would be worth £23,750/ha. It has to be stated though, that its value reaches £32,195/ha before being reduced by the averaged value of carbon emissions. Carbon emissions create a loss of a quarter of the value whose provision represents 54% alongside cultural 34%, and biodiversity 13% values.

Another significant aspect of land cover is the biodiversity of rivers, though these will not be significantly disturbed by a rail crossing as bridges will indeed be built. Lakes and rivers do not play roles in carbon sequestration, contrary to fens and marshes. However, lakes have the most important biodiversity value (£96,380/ha), due to the cost of recreating inland bodies, as well as recreating them (£11,830/ha). Fen ecosystems amount to a total replacement cost of £98,249/ha, while lakes cost £111,372/ha.

In the case of grasslands, two main types have been considered: natural and managed. Cultural values for playgrounds and sports pitches can be considered as managed grasslands. They are relatively similar, attributed with values of £87,620/ha for natural grasslands and £89,415/ha for managed ones. Nevertheless, natural grassland provides greater biodiversity and carbon sequestration services whereas managed grassland has a greater cultural value.

Overall, replacement costs, caused by biodiversity and ecosystems goods and services losses from woods, lakes or fens would result in expensive replacment costs. Grasslands, rivers, and woods are highly valued for their welfare contribution, as well as grass and arable lands for provisions. Woods sequester the most significant amount of CO_2.

5.2 Pollution

Air pollution occurs throughout rail construction. For one km of a double-track rail line built, around 2,000 t CO_2e are globally emitted into the atmosphere. Whereas 9.7 t CO_2e/km of nitrogen oxides and 3 t CO_2e/km of carbon monoxides are emitted locally.

Trains pollute in operation with emissions estimated to be equal to 0.0040 kg CO_2e /passenger/km (The Community of European Railway, 2015). This figure is believed to be approximately three times less than a car journey.

With 10,000 daily train trips (Jacobs, 2016) nearing a distance of 30kms, replacing the same amount of car trips, it represents a reduction of 21 t CO2e/day not being emitted into the atmosphere. Air pollution of rail operations is relatively low, representing 2% of total British transport pollution.

As an example, the amount of carbon emitted to create a 50km rail route would be negligible after 4,762 days (approximately 13 years) of operation.

5.2.1 Differences Between Electric and Diesel Trains

The train considered would carry 400 passengers per journey. In order to select which type of train (diesel or electric) would be more beneficial for the environment, several considerations where evaluated and are compared in Table 5-4. While, GHG emissions are general figures, air pollution is taken from the London Paddington case study by Chong, Swanson and Boies (2015).

Table 5-4 : Comparison between Electric and Diesel Trains.

	Electric	Diesel
GHG emissions operations (kgCO_2e/km)	None	28
GHG emissions electricity (kgCO_2e/km)	20	None
NO2 air concentration (ppb)	None to the rail surroundings	49 to 120
$PM_{2.5}$ air concentration (µg/m³)	None to the rail surroundings	2 to 68
Track wear costs (£/km)	0.05	0.06
Fuel costs (£/km)	0.16	0.29
Maintenance costs (£/km)	0.25	0.37
Construction costs (2 tracks) (m£/km)	24 + 3.4 = 27.4	24

The mean European standard is 106 ppb for NOx concentration and 25 µg/m³ for $PM^{2.5}$. Diesel trains can regularly exceed those standards as well as produce more GHG per km. Hence, electric trains, which do not pollute the surroundings of the rail line, have much less environmental impact and therefore more appeal.

It has to be stated that long-term exposure of particulate matter (PM^{10} and $PM^{2.5}$) can cause damage to lung tissues and reduce lung functionality and people's respiratory and cardiovascular system can be adversely affected, especially children, seniors, asthmatics and people who often exercise outside (HS2, 2017). Long-term exposure to NO_2 can result in symptoms of bronchitis, especially in asthmatic children (HS2, 2017).

More than their environmental benefits, electric trains are less costly to run, at £0.46/km for fuel, maintenance and track wear costs, against £0.72/km for diesel trains (Railway Technology, 2010). Electrifying tracks would cost £3.4m/km for a double track rail line similar to the one planned from Bedford to Cambridge (Clark, 2015).

6 Natural Capital of the Routes

6.1 Woodlands

Natural capital will not be spoiled if using either existing rail lines or tunnels. Tunnels on the EWR route would save ancient woodland from disturbance while existing rails would avoid the crossing of 2.4 and 1.3 ha using the 5th Studio option and the Cranfield project team proposal.

Globally, the EWR route, crossing ancient woodlands, is the costlier in many ecosystem services, from the total losses to welfare and biodiversity riches. However, more carbon is yearly caught by the wood possibly crossed by the Northern Route. It remains negligible, though, compared to the extent of disruption that would be caused by the EWR route on woods.

Tables 6-1, 6-2 and 6-3 have been ordered from the least impacting route on the wood assets to the costliest. For the sake of clarity and visibility, carbon and biodiversity financial values are not shown in these tables. They are however well accounted for in the "Planned financial loss".

Table 6-1 : Impacts on woodlands along the EWR route.

	Type	Age	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Carbon caught yearly (t CO2e)	Provision discounted (£)	Planned financial loss (£)
EWR	Broadleaf	Unknown	4	198,020	94	2,676	16	5,222	992,555
	Broadleaf	ANCIENT	1	82,868	59	1,217	2	226	569,839
	Coniferous	Unknown	0	0	-	-	-	0	0
	TOTAL		**5.65**	**280,888**	**153**	**3,893**	**18**	**5,448**	**1,562,394**

Table 6-2 : Impacts on woodlands along the Northern Route.

	Type	Age	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Carbon caught yearly (t CO2e)	Provision discounted (£)	Planned financial loss (£)
CUR	Broadleaf	Unknown	4	177,652	98	2,503	15	4,885	1,004,959
	Broadleaf	ANCIENT	0	0	-	-	-	0	0
	Coniferous	Unknown	0	23,953	7	107	3	523	69,813
	TOTAL		**4.35**	**201,604**	**105**	**2,610**	**18**	**5,408**	**1,074,772**

Table 6-3 : Impacts on woodlands along the 5th Studio route.

	Type	Age	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Carbon caught yearly (t CO2e)	Provision discounted (£)	Planned financial loss (£)
5th studio	Broadleaf	Unknown	3	163,478	75	1,842	11	3,595	765,554
	Broadleaf	ANCIENT	0	0	-	-	-	0	0
	Coniferous	Unknown	0	0	-	-	-	0	0
	TOTAL		**2.89**	**163,478**	**75**	**1,842**	**11**	**3,595**	**765,554**

If a biodiversity gain of 15% is sought, it would increase the replacement values needed to 176 ha, 121 ha and 86 ha for the EWR, Northern Route and 5th Studio routes, respectively.

It has to be noticed that woodland biodiversity is more impacted and spoiled when the route affects a wider percentage of its area. Indeed, fragmentations and size reductions are likely to create unviable areas for cohesive habitats (further details are presented in Appendices G and H). Hence, the value of biodiversity impacted can be much higher than predicted. The area being reflected here is based solely on the woodland affected by the 22-metre track land take.

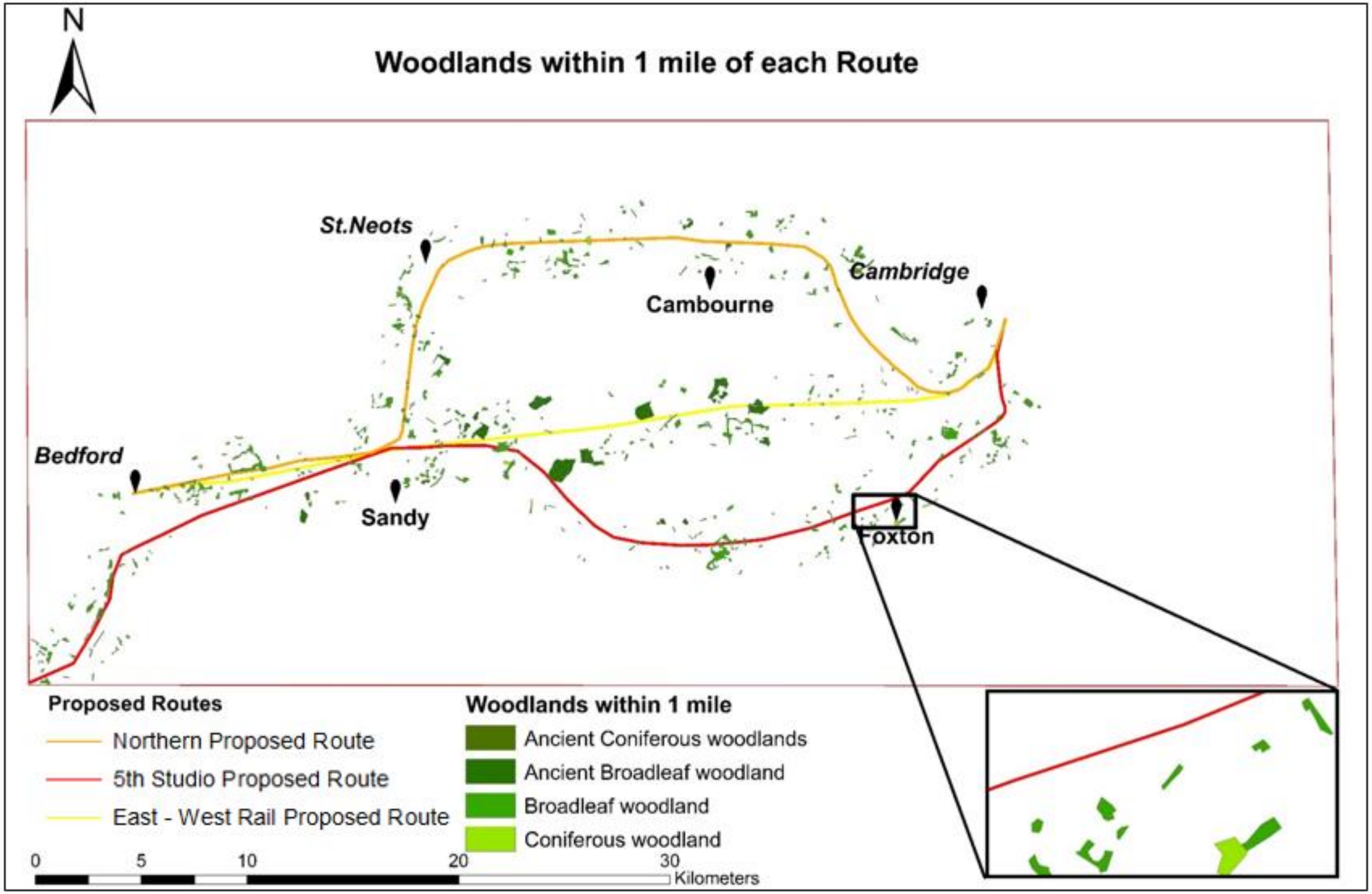

Figure 6-1: Woodland within the study areas 1-mile buffer-zone.

6.2 Wetlands

Rivers have a negligible biodiversity loss when crossed by rail lines. Indeed, despite a temporary effect due to construction works, the use of bridges would greatly reduce the permanent impact associated with the rail line. Rivers and lakes also do not sequester carbon.

Freshwater areas are quite scarce in the area. The 5th Studio route would create the most disturbance over standing water, but the small size of the disturbed surface (0.76ha) with a potential financial loss of £84,047 seems negligible when compared to the saving the 5th Studio route would create in reference to wood areas. The 5th Studio route presents a loss of 2.89 ha in comparison to the 5.65 ha which could be lost from the EWR proposal, including the loss of 1.45 ha of ancient woodlands. This is reflected by a potential loss difference of £796,840

Tables 6-4, 6-5 and 6-6 have been ordered from the least impacting route on the wetlands assets to the costliest. For the sake of clarity and visibility, carbon and biodiversity financial values are not shown in these tables. They are however well accounted for in the "Planned financial loss".

Table 6-4 : Impacts on wetlands along the EWR route.

Name	Type	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Carbon caught yearly (t CO2e)	Provision discounted (£)	Planned financial loss (£)
Bedford River Great Ouse	River	**0**	**9,599**	**0**	**0**	**0**	**550**	**10,149**

Table 6-5 : Impacts on wetlands along the Northern Route.

Name	Type	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Carbon caught yearly (t CO2e)	Provision discounted (£)	Planned financial loss (£)
Boating Lake	Standing water	0	184	1	0	0	510	16,250
River Great Ousan	River	0	624	0	0	0	36	659
Cambourne	Standing water	0	1,530	0	0	0	409	10,241
TOTAL		**0**	**2,338**	**1**	**0**	**0**	**955**	**27,150**

Table 6-6 : Impacts on wetlands along the 5th studio route.

Name	Type	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Carbon caught yearly (t CO2e)	Provision discounted (£)	Planned financial loss (£)
Marston Vale Millenium	Standing water	0	1,673	1	0	0	447	15,745
Marston Vale Millenium	Standing water	0	2,720	1	0	0	727	25,605
Harrowden	Standing water	0	4,540	2	0	0	1,214	42,738
TOTAL		**1**	**8,932**	**3**	**0**	**0**	**2,388**	**84,087**

If a biodiversity gain of 15% is sought, it would increase the replacement needed to 3.45 ha and 1.15 ha for the Northern Route and 5^{th} Studio routes while the EWR proposal will not increase the biodiversity. Figure 6-2 gives a detail of the freshwater bodies across the routes.

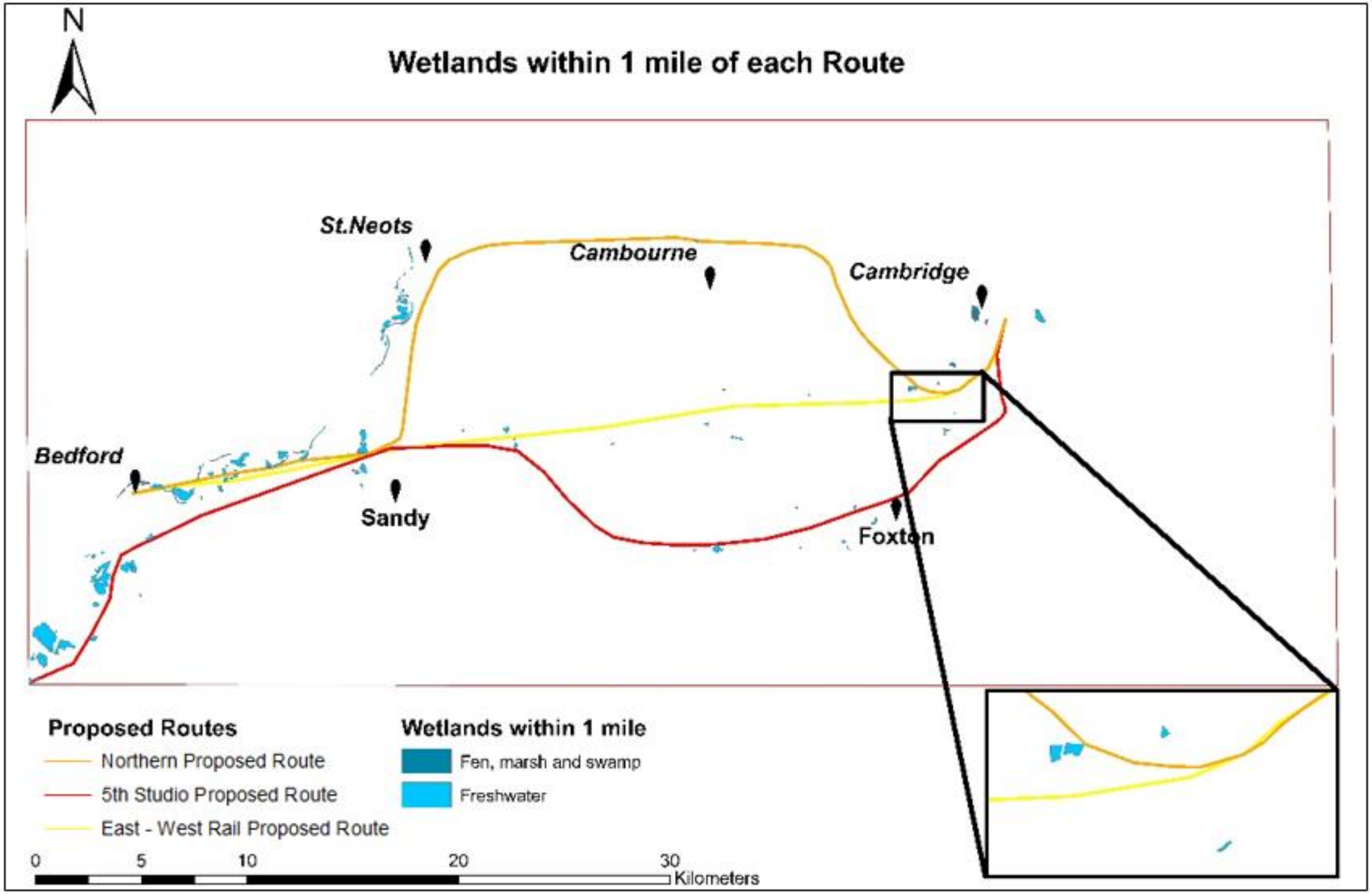

Figure 6-2 : Freshwater bodies and wetlands within the study areas 1-mile buffer-zone.

6.3 Agricultural Land

Agricultural lands are the main land cover of the study area. EWR has the greatest impact on Grade 1 land. The Northern Route has the least impact on Grade 1 land, however, the total area impacted by the route is greater than 75 ha. This is double the land disturbed by the EWR proposal. Overall the EWR route has the least impact on arable land, however, the substantial disruption to other land covers could render this benefit as negligible. Fortunately tunnels on the 5th Studio route would result in the avoidance of disrupting some agricultural land. However, all of the routes will have an adverse effect of greater than 5 ha on Grade 1 and 25 ha on Grade 2 agricultural land.

Tables 6-7, 6-8 and 6-9 have been ordered from the least impacting route on the arable assets to the costliest. For the sake of clarity and visibility, carbon and biodiversity financial values are not shown in these tables. They are however well accounted for in the “Planned financial loss”.

Table 6-7 : Impacts on arable lands along the. EWR route

	Type	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Provision discounted (£)	Planned financial loss (£)
EWR	Grade 1	9	100,958	28	94	218,049	280,147
	Grade 2	25	279,759	76	261	561,063	733,139
	Grade 3	0	0	0	0	0	0
	Grade 4	0	0	0	0	0	0
	TOTAL	**34.59**	**380,717**	**104**	**355**	**779,113**	**1,013,286**

Table 6-8 : Impacts on arable lands along the Northern Route.

	Type	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Provision discounted (£)	Planned financial loss (£)
CUR	Grade 1	6	63,612	17	59	137,388	176,515
	Grade 2	51	566,140	154	527	1,135,407	1,483,631
	Grade 3	10	113,310	31	106	171,309	241,004
	Grade 4	4	38,927	11	36	45,040	68,984
	TOTAL	**71.05**	**781,989**	**213**	**729**	**1,489,144**	**1,970,133**

Table 6-9 : Impacts on arable lands along the 5th Studio route.

	Type	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Provision discounted (£)	Planned financial loss (£)
5th studio	Grade 1	8	92,269	25	86	199,282	256,035
	Grade 2	34	374,331	102	349	750,730	980,975
	Grade 3	4	39,439	11	37	59,626	83,884
	Grade 4	3	36,151	10	34	41,828	64,064
	TOTAL	**49.26**	**542,190**	**148**	**505**	**1,051,466**	**1,384,958**

If a biodiversity gain of 15% is sought, it would increase the replacement needed to 119 ha, 245 ha and 170 ha respectively for the EWR, Northern Route and 5th Studio routes.

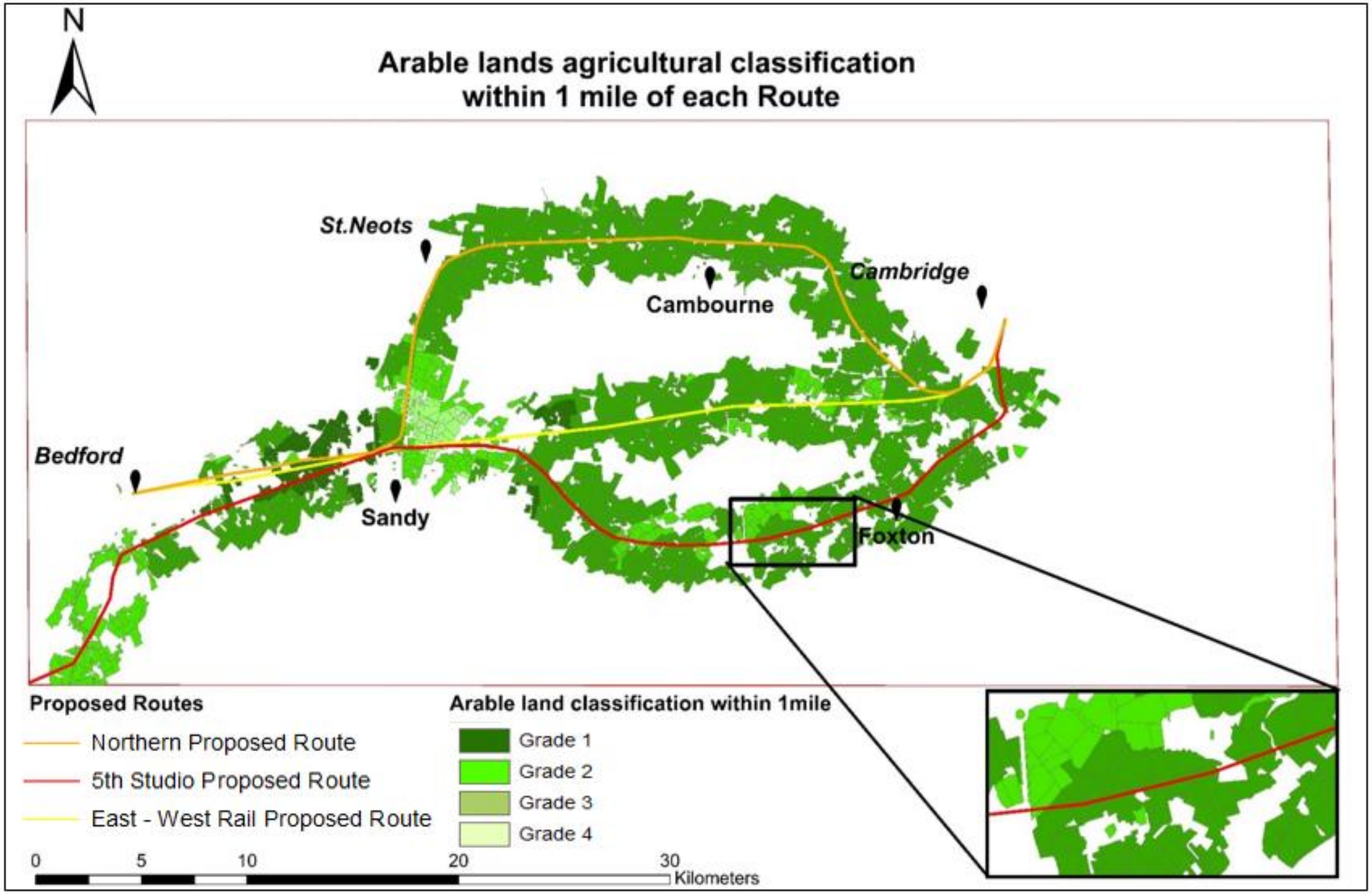

Figure 6-3 : Arable and horticulture affected areas within the study areas 1-mile buffer-zone.

6.4 Grasslands

Despite the use of tunnels preserving hectares of grassland from suppression, it is the Northern Route without any tunnels which would disturb least grassland. Though being the shortest option, the EWR suggestion would affect more grasslands. Its amount of traversed grassland is similar to the 5th Studio option.

'Other Regulating Services' have not been accounted for with wood, freshwater or arable land cover evaluation. The uncertainty about their quantification and benefits in the study area prevented their use. Nevertheless, they have been presented here as an example, to value their importance. For grasslands, they represent water purification, erosion prevention, nutrient cycling, and pollination. They have been extracted from the TEEB database (European Commission, 2015). Unfortunately, due to software restrictions, solely maps with improved grasslands were created. This contrasts with the specific valuation which had led to many different types of grasslands.

Tables 6-10, 6-11 and 6-12 have been ordered from the least impacting route on the grassland assets to the costliest. For the sake of clarity and visibility, carbon and biodiversity financial values are not shown in these tables. They are however well accounted for in the "Planned financial loss".

Table 6-10 : Impacts on grasslands along the EWR route.

	Type	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Other regulating services (£)	Provision discounted (£)	Planned financial loss (£)
EWR	Improved grassland	15	172750	28	5072	118997	246021	807601
	Tunnel	2	27966	4	821	19264	39827	-130738
	TOTAL	**13**	**144785**	**23**	**4251**	**99733**	**206194**	**676863**

Table 6-11 : Impacts on grasslands along the Northern Route.

	Type	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Other regulating services (£)	Provision discounted (£)	Planned financial loss (£)
CUR	Improved grassland	**6**	**71732**	**11**	**2106**	**49412**	**102157**	**335346**

Table 6-12 : Impacts on grasslands along the 5th Studio route.

	Type	Area crossed (22m-wide railway)	Welfare Riches (£)	Biodiversity importance (replacement ha needed)	Carbon sequestrated (t CO2e)	Other regulating services (£)	Provision discounted (£)	Planned financial loss (£)
5th studio	Improved grassland	15	166366	27	4884	114599	236929	777755
	Tunnel 1	3	33348	5	979	22972	47493	-155902
	Tunnel 2	0	1352	0	40	931	1925	-6320
	TOTAL	**12**	**131666**	**21**	**3865**	**90696**	**187511**	**615532**

If a biodiversity gain of 15% is sought, it would increase the replacement needed to 27 ha, 13 ha and 24 ha respectively for the EWR, Northern Route and 5th Studio routes.

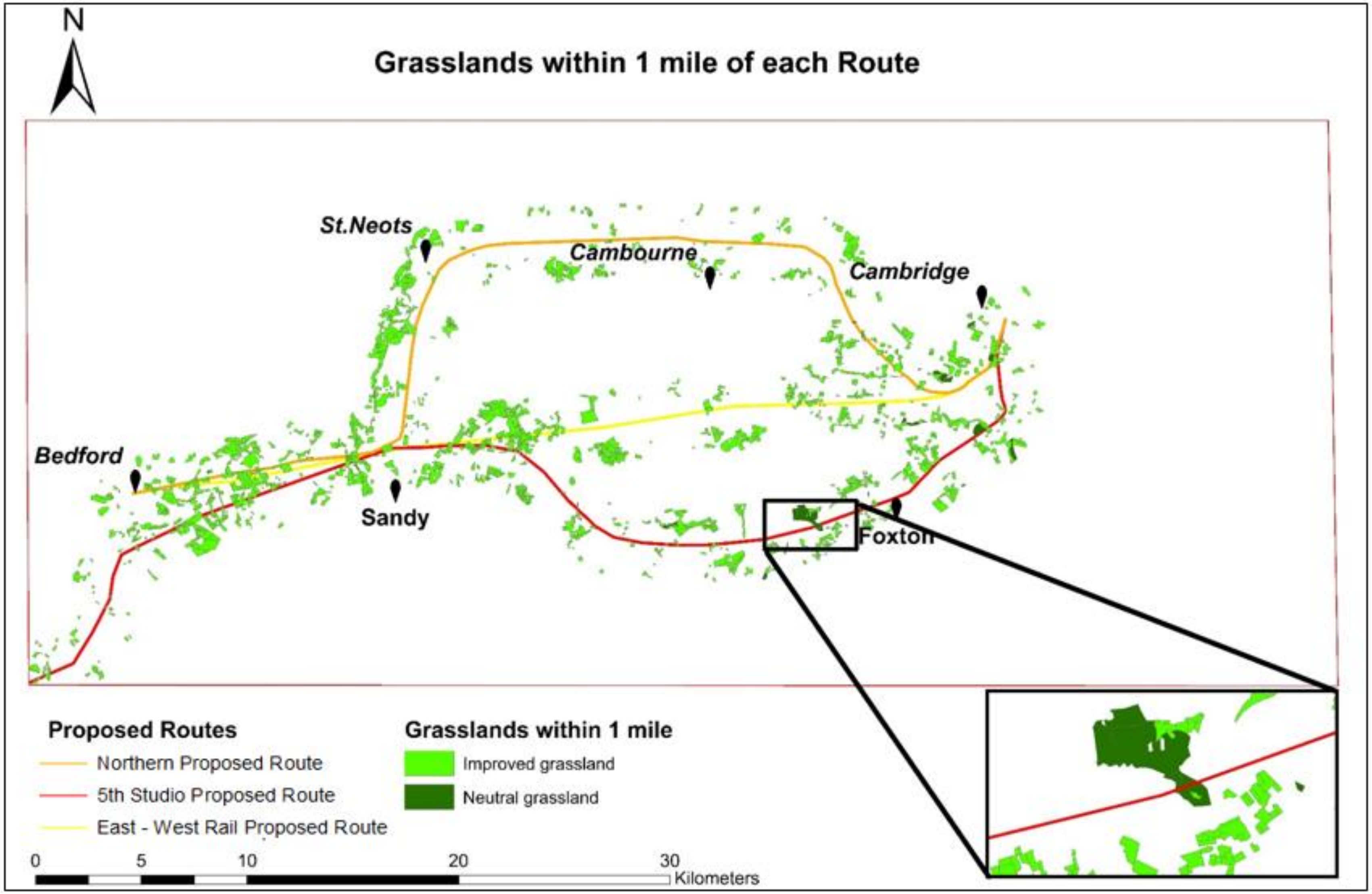

Figure 6-4 : Grasslands within the study areas 1-mile buffer-zone.

6.5 Summary of Land Cover Impacts

Tonnes of carbon lost cannot be compared with hectares of replacement or cereal yield. Thus, all the potential services provided by an ecosystem for society had to be levelled with a common factor. Finances stand as this common reference and a good indicator of the services importance.

Within Tables 6-13, 6-14 and 6-15, the disturbance of the environment for each of the three routes is summarised via its ecosystem losses. Those losses are financially presented and account for all the services' values presented in this report.

Globally, the Cranfield project team proposal presents the worst environmental impact.

Table 6-13 : Potential financial losses associated with the natural capital of the EWR route.

	Land cover	Financial impact on ecosystem services (£)	Replacement with a 15% biodiversity gain (ha)	Impact Ranking in comparison with the 2 other routes
EWR	Woodlands	1,562,394	176	1
	Wetlands	10,149	0	3
	Arable lands	1,013,286	119	3
	Grasslands	676,863	27	1
	TOTAL	**3,262,692**	**322**	**2**

Table 6-14 : Potential financial losses associated with the natural capital of the Northern Route.

	Land cover	Financial impact on ecosystem services (£)	Replacement with a 15% biodiversity gain (ha)	Impact Ranking in comparison with the 2 other routes
CUR	Woodlands	1,074,772	121	2
	Wetlands	27,150	1	2
	Arable lands	1,970,133	245	1
	Grasslands	335,346	13	3
	TOTAL	**3,407,401**	**380**	**1**

Table 6-15 : Potential financial losses associated with the natural capital of 5th Studio route.

	Land cover	Financial impact on ecosystem services (£)	Replacement with a 15% biodiversity gain (ha)	Impact Ranking in comparison with the 2 other routes
5th studio	Woodlands	765,554	86	3
	Wetlands	84,087	4	1
	Arable lands	1,384,958	170	2
	Grasslands	615,532	24	2
	TOTAL	**2,850,131**	**284**	**3**

The following Figures 6-5 to 6-13 present different characteristics of selected areas of the routes. Hence, we can see the types of land cover that the width of 22 meters of the route is crossing such as near Bedford, St Neots and Cambridge. According to HS2, (2012) , the minimum recommended width for a railway rail is 11 m.

Consequently, it is assumed that the railway under study is a double-track line therefore, the routes will impacted over 22 m of the land cover.

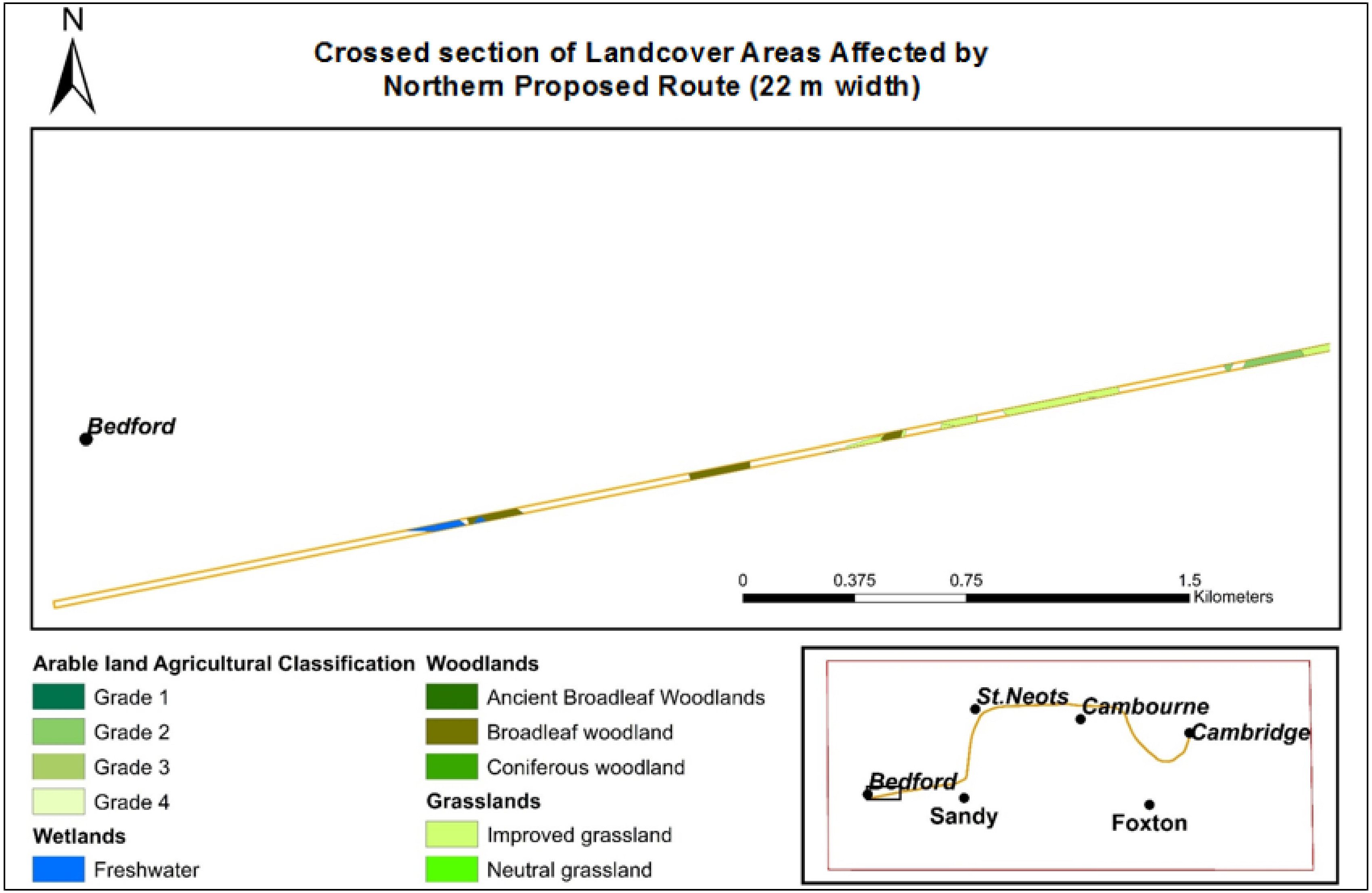

Figure 6-5: Loss areas of different land covers by Northern Route near Bedford town.

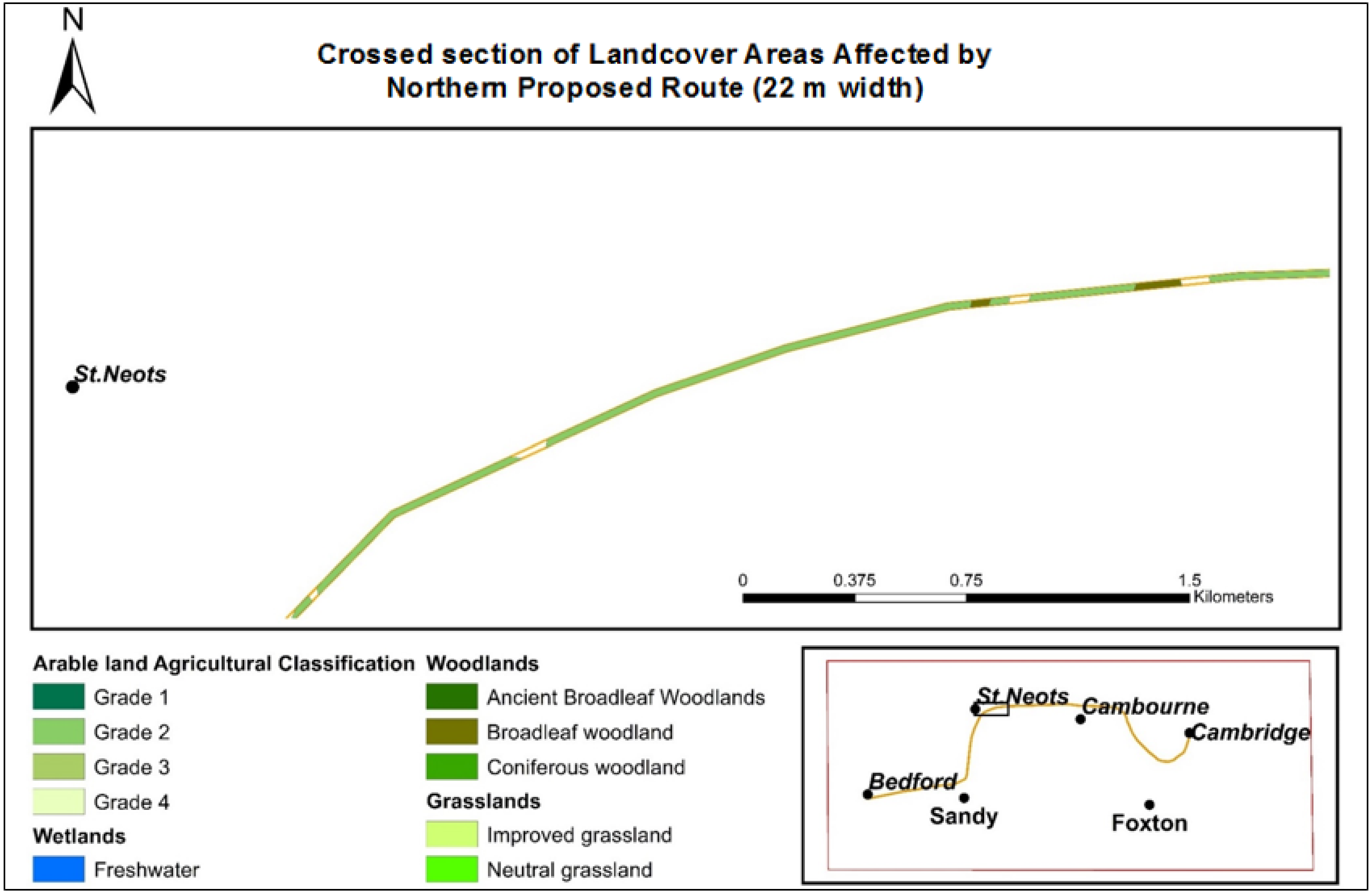

Figure 6-6: Loss areas of different land covers by Northern Route near St. Neots.

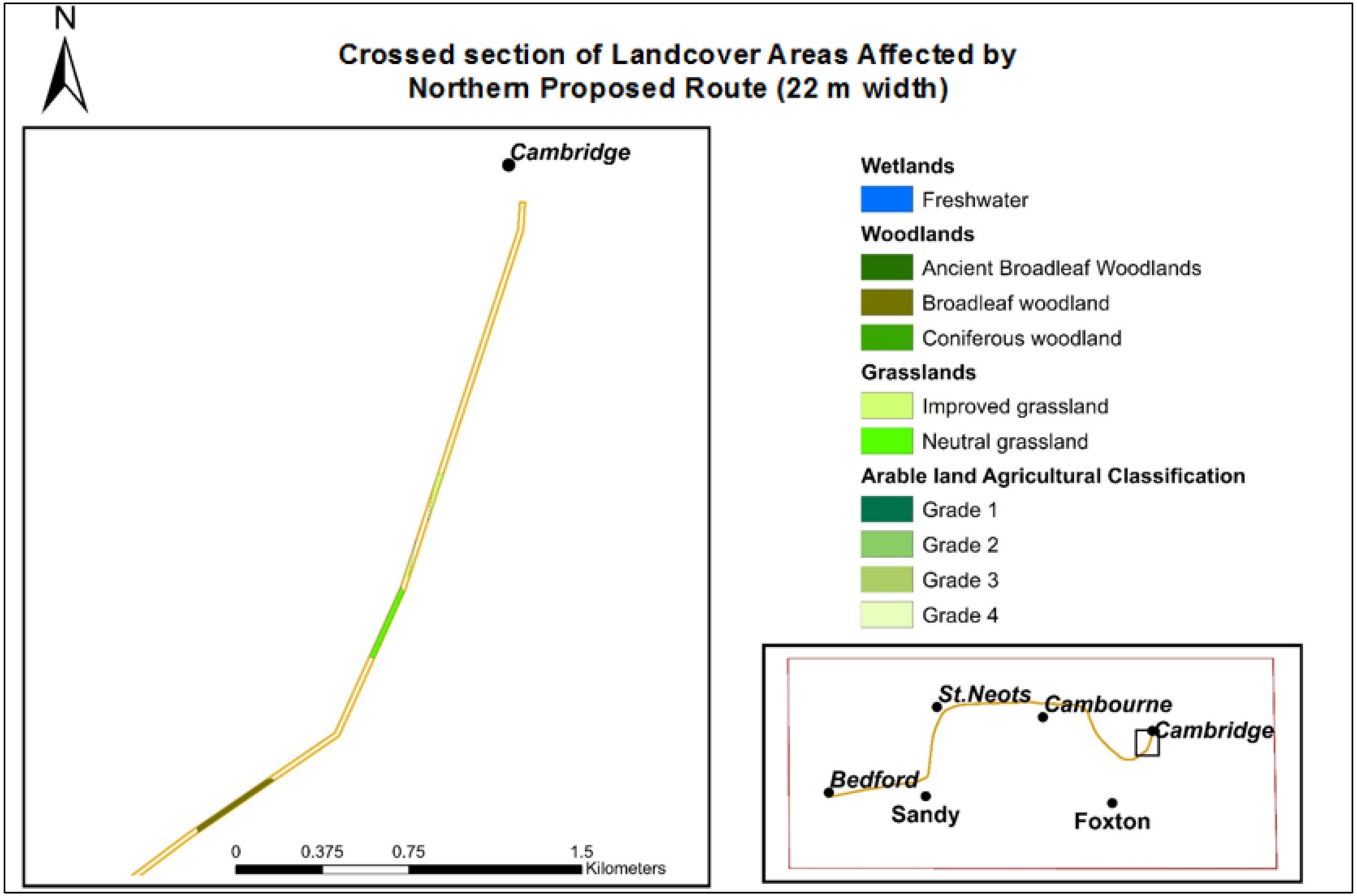

Figure 6-7: Loss areas of different land covers by Northern Route near Cambridge.

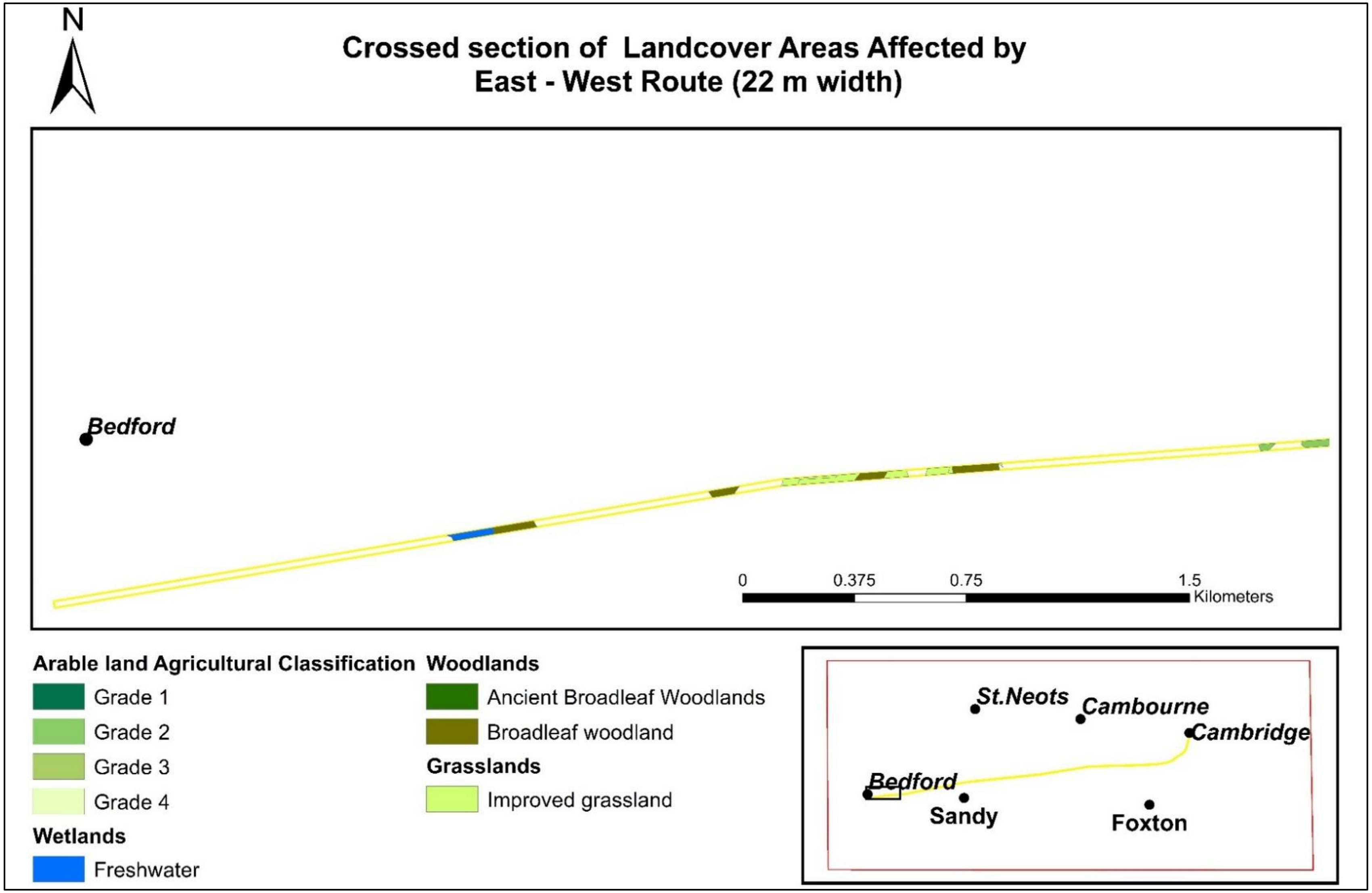

Figure 6-8: Loss areas of different land covers by EWR route near Bedford town.

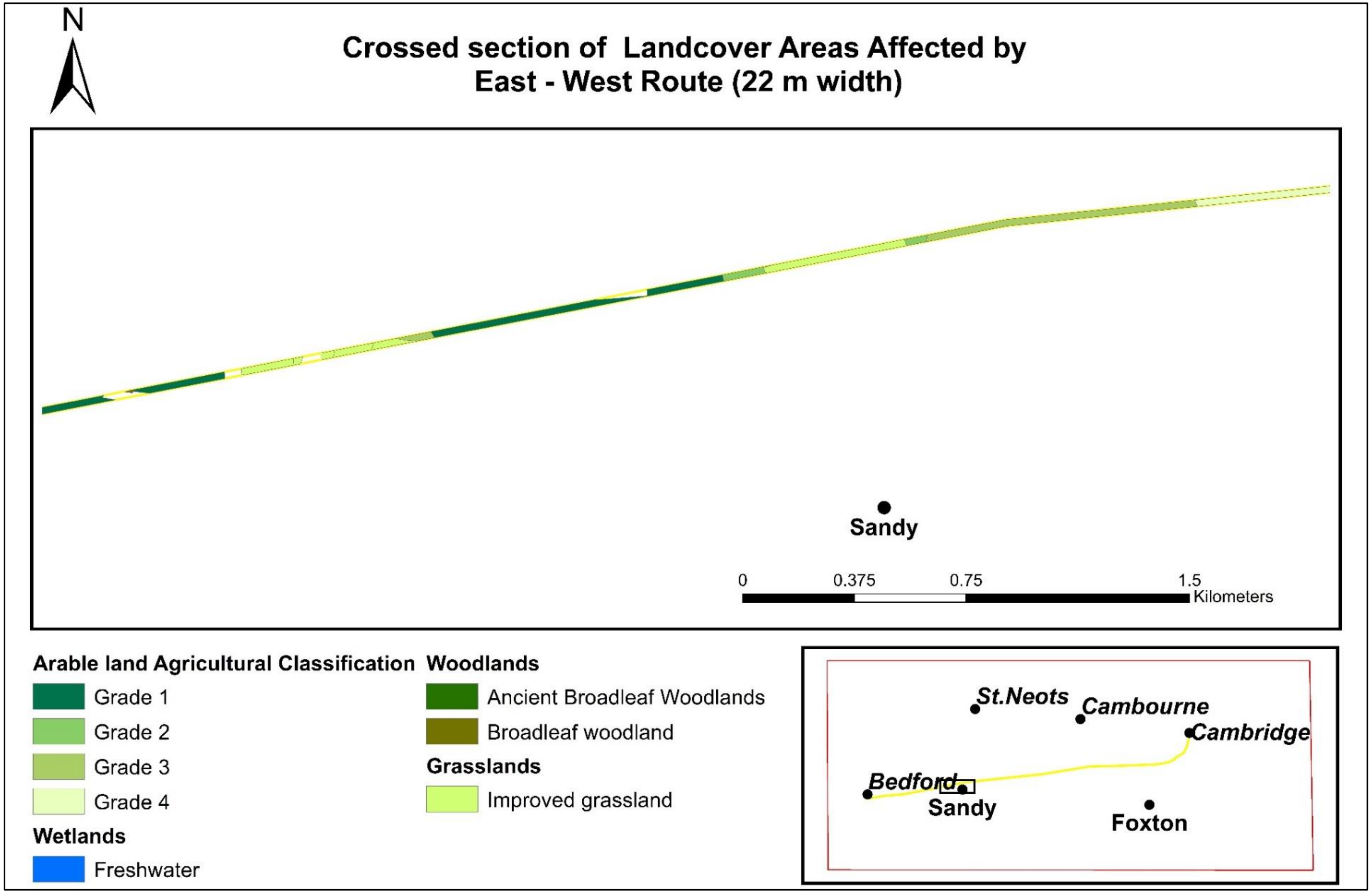

Figure 6-9: Loss areas of different land covers by EWR route near Sandy.

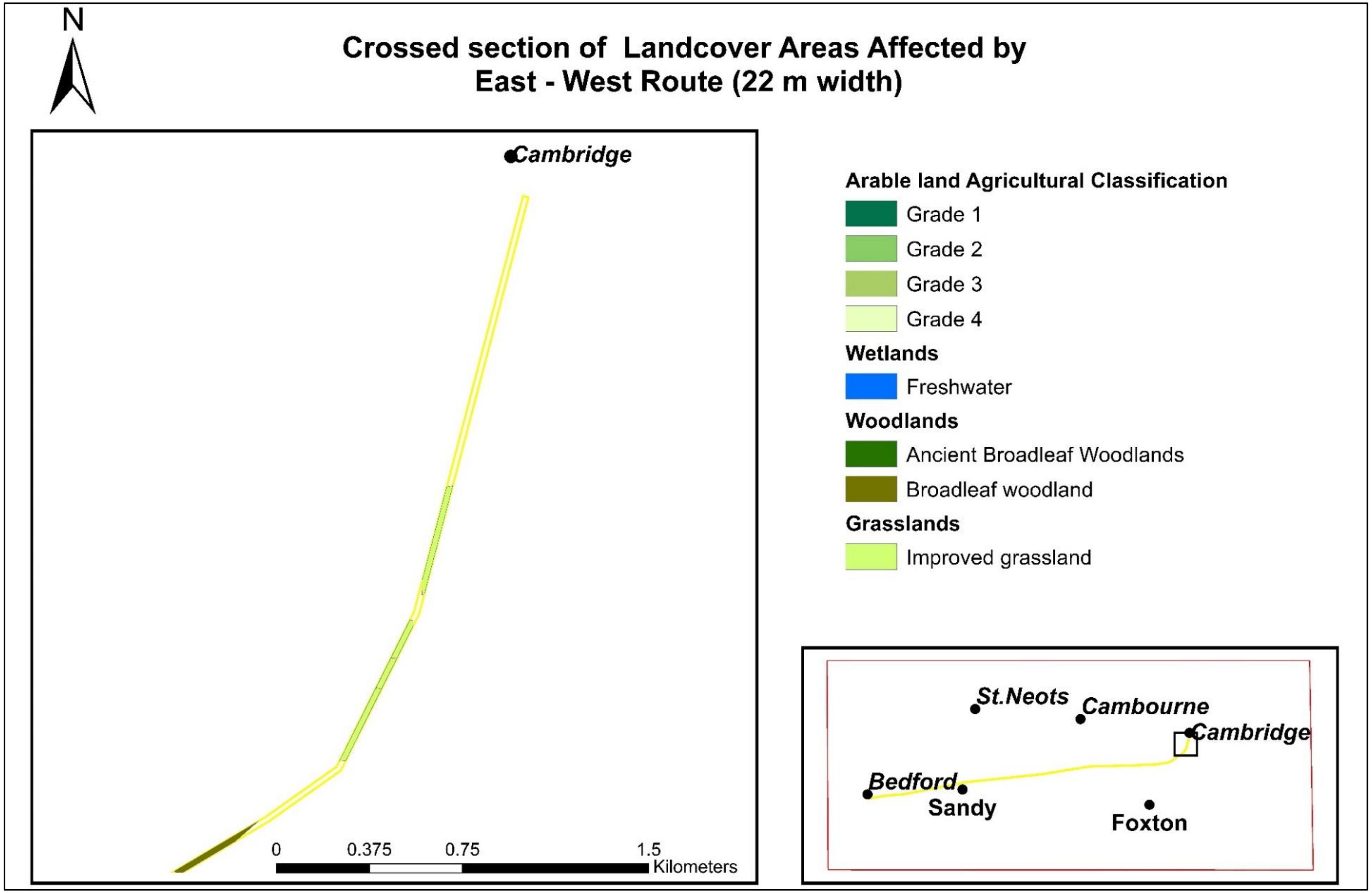

Figure 6-10: Loss areas of different land covers by EWR route near Cambridge.

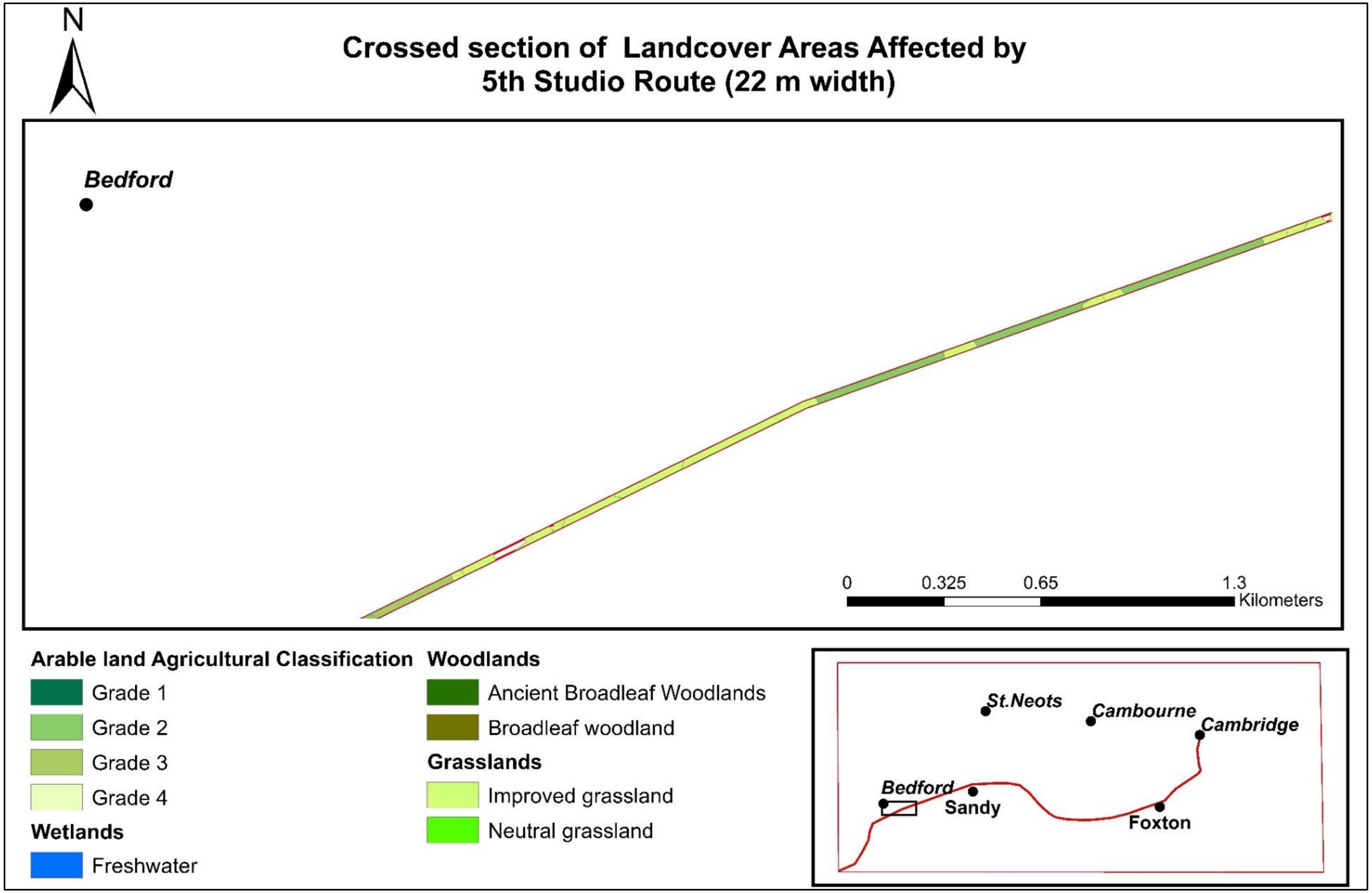

Figure 6-11: Loss areas of different land covers by 5th Studio route near Bedford.

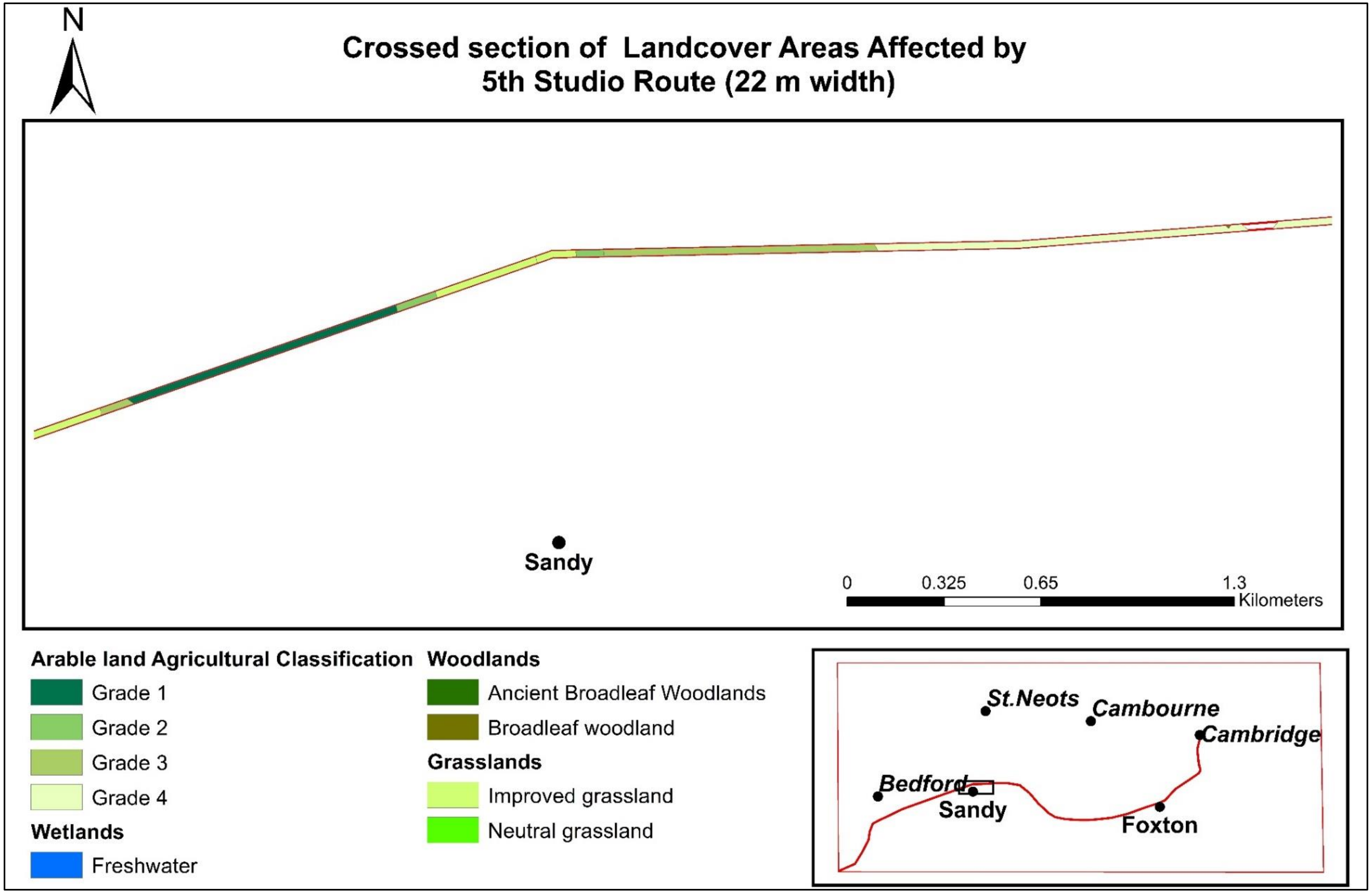

Figure 6-12: Loss areas of different land covers by 5th Studio route near Sandy.

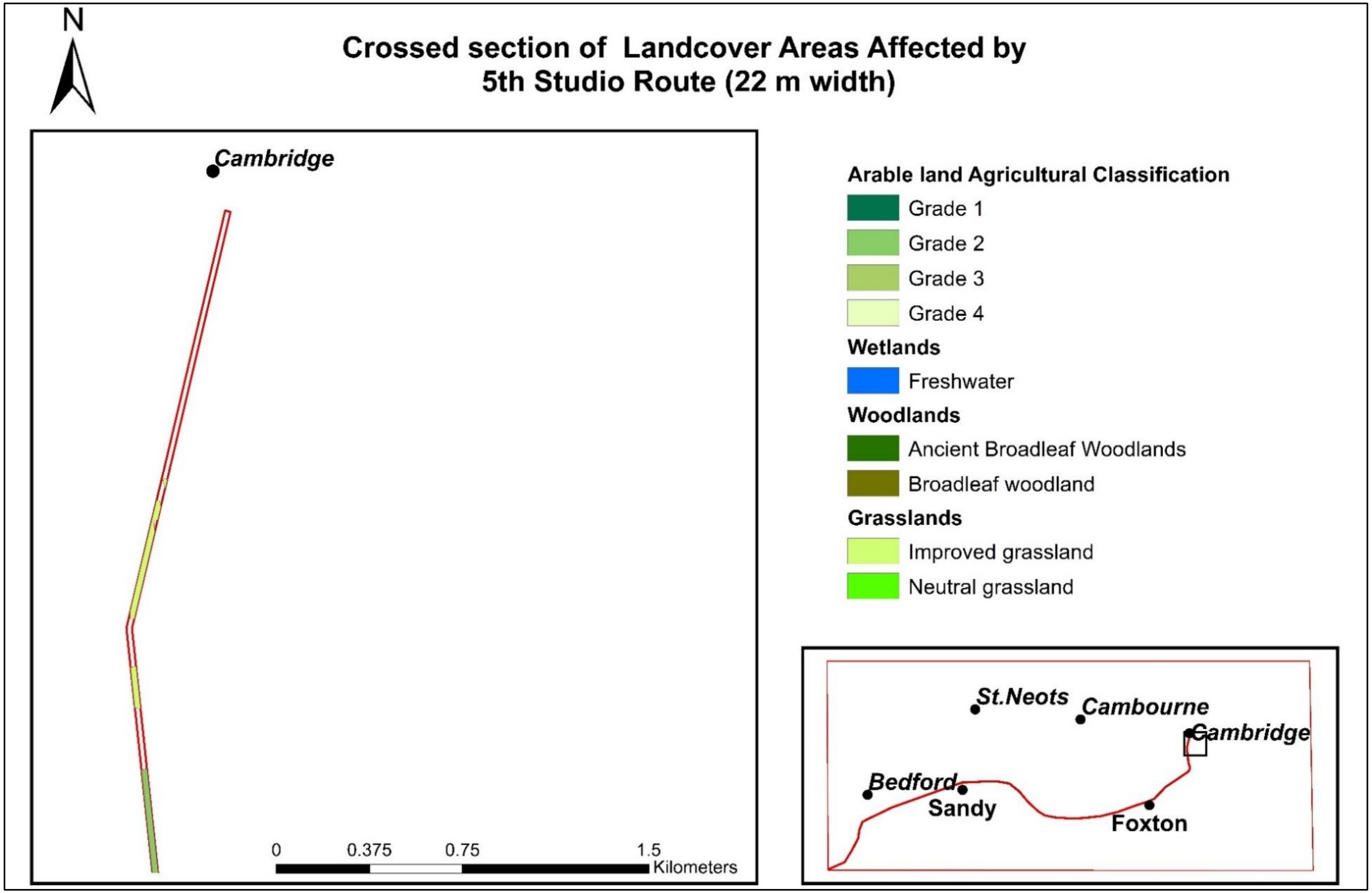

Figure 6-13: Loss areas of different land covers by 5th Studio route near Cambridge.

6.7 Pollution Associated with the Rail Lines Routes

As said above, and generally speaking, trains replacing cars between Bedford and Cambridge may daily reduce GHG emission by 21 t CO_2e. Electric trains are save 8 kg of CO_2e/km compared to diesel ones. Also, they do not pollute the air or their surrounding areas. They are environmentally friendly and even cheaper to run. However, investment is required to electrify the lines. For a double-track rail line, £3.4 m/km is needed. With combined savings of £0.26/km and considering 20 daily Bedford to Cambridge returns the investment would be paid back after 327 days (436 days if 15 daily returns). Table 6-16 demonstrates how all options are equal regarding the investment aspect, hence, longer routes create more savings even when combined with substantial investments. Electrifying rail would reduce daily GHG emissions by almost 30% and avoid the pollution of air through particles or nitrous oxides that can have negative impacts on highly populated area such at Bedford, Cambridge and St Neots. The air pollution would be rather similar in every option with highly populated areas, such as Bedford and Cambridge. However, the Cranfield project team proposal would cross an additional populated area, St Neots. The town of St Neots is already exposed to rail line emissions and the inhabitants are likely to provide some form of opposition.

GHG will be emitted in all cases for the purposes of construction, at an extent of 2,000 t CO2e/km. Pollution impact summary for each route is shown in Table 6-16.

Table 6-16 : Pollution impact summary for each route.

Pollution criteria	EWR	Northern Route	5th Studio
Distance Bedford-Cambridge (m)	43667	53773	54865
GHG emissions diesel (t CO2e/day)	48.9	60.2	61.4
GHG emissions electric (t CO2e/day)	34.9	43.0	43.9
Investment diesel to electric (£/m)	148.4678	182.8282	186.541
Return on investment electric/diesel (days)	326.9	326.9	326.9

7 Ready Reckoner

The term ‘Ready Reckoner’, is defined accordingly to the Oxford dictionary as “a book or table listing standard numerical calculations or other kinds of information presented formulaically”. Usually, it contains pre-calculated values that ease the estimation of new values. It is a useful tool that has been used in multiple disciplines of research.

A ‘Ready Reckoner’ could be used in natural capital asset assessment as a tool for the estimation of investment opportunities amongst other utilities. It is designed to provide a more rapid analysis of the economic benefits obtained as a consequence of land cover change when a new habitat is created. In spite of such a tool being only available for wetland creation, it could be utilised for all the land covers under study. In order to create a ready reckoner for the different land covers, pre-calculated values, that could be obtained from different literature sources for habitat type and areas and for the different ecosystem services among others, should be established in advance, as well as the use of alternate models and tools to provide economic projections, in order to estimate future scenarios.

<u>Case study: Wetland</u>

A ‘Ready Reckoner’ table to estimate the economic value of creating a wetland habitat was created following the UK guidance on valuation of wetland by Brouwer *et al.* (2010), among other documents. With that tool, the estimated economic value obtained from creating a wetland while removing an existing land cover is calculated. For that purpose, it is important to set down the creation and maintenance conditions of the new habitat, when it is going to be created and where it is going to be allocated, among other requirements.

One of the main impacts that it is evaluated with that tool, due to the economic impact that it has, is the net annual carbon sequestration. According to *Dawson and Smith* (Natural England, 2010), the wetland could store between 2.2 - 4.6 tCe/ha/yr more than arable land for example, and it has a high economic impact following the carbon price estimated by Department of Energy and Climate Change (DECC) (Department of Energy and Climate Change, 2011).

With the purpose of comparing the economic value of change of different land cover types into wetland, some creational and maintenance conditions were set down. As a consequence, 10 ha of different land will be changed into wetland, a scarce habitat in the UK, by 2030. The site management will be guaranteed for 25 years and this will be an open public site. It is assumed as well, that due to the housing development in the arc area, the wetland created, will be less than 200m from a village or town. Appendix I contains the table with all the values as well as a summary of the literature source that was used for the development of the ready reckoner. However, Table 7-1 summarises the economic values obtained.

Table 7-1 : Estimated economic values obtained from the creation of a new wetland habitat in an existing land cover.

Existing land use	New habitat creation	Lower economic estimate	Central economic estimate	Upper economic estimate
Arable	Inland marsh/fen/reedbed	£277,694	£496,027	£895,063
Grassland		£228,798	£421,992	£811,958
Brownfield		£228,798	£421,992	£811,958
Degraded wetland		£204,351	£295,075	£467,665

After review, the results obtained clearly signify that the most economical option is to create the new wetland habitat in existing arable land. This is mostly due to the carbon value. As mentioned before, a wetland can store more carbon than arable land, therefore it will increment their value. While the central carbon value estimated for habitat change from arable to wetland is £239,732; the value is just £38,780 if the change is from degraded wetland. The minor increase of the central economic estimate is due to the little change in the ability of carbon sequestration by wetland into a more specific aquatic habitat. When compared to other land uses it is understandably lower. Therefore, the creation of an inland marsh or reedbeds in a degraded wetland will render a smaller value in comparison to the creation of reedbed habitat from arable land.

Developing a ‘Ready Reckoner’ for different land covers would be a useful tool in assisting with locating and selecting areas for natural capital investment opportunities. Decisions when assessing an areas potential worth, would be made considerably easier in relation to biodiversity offsetting from infrastructure development.

8 Conclusions, Reinvestment and Communication

Comparison between the three proposed routes can be seen Table 8-1. When presented in such a format, the findings become clearer and easier to understand. The great number of variables at stake in decision making of infrastructure site selection becomes apparent and the inevitable consequences of such development can then be observed and addressed. Such conclusions allow comparison between routes, for example one may have the greatest impact on land cover and associated habitats but in the long term, less of an impact on air quality, therefore, having a lower carbon footprint, and a smaller whole life environmental cost.

Table 8-1 : Main Study Conclusions.

	EWR	Northern Route	5th Studio
Environmental Benefits	-Least operation emissions -Least impact on freshwater -Least impact on agriculture	-Least impact on Grade-1 agricultural land -Least impact on grasslands	-Least construction emissions -Least impact on woods -Least general impact on land covers
Other Benefits	-Fastest journey (16 min)	-Lowest construction costs -Simplest to construct	-Shortest distance to build
Environmental Dis-benefits	-Significant impact on woods -1.5 ha of ancient wood lost -Greatest number of grasslands traversed	-Suppression of cycling route -Greatest construction emissions -Additional air pollution St Neots -High potential for flooding -Highest general impact on land covers	-Greatest operation emissions -Disturbance of some wetlands
Other Dis-benefits	- Greatest number of buildings on route - One tunnel to build - One bridge to build	- Longest distance to build - Four bridges to build - Greater need for noise barriers	- Longest distance to run - Highest construction costs - Two tunnels to build

The following conclusions can be drawn from Table 8-1:

- ✓ East-West Rail presents the **fastest journey** with 16 minutes. Despite this the alternate options stand at approximately around 20 minutes from Bedford to Cambridge.
- ✓ Northern Route offers the **cheapest** solution with all the potential engineering costs considered (noise barriers, tunnels, bridges, housing compensations,

distance to build). The assumption to utilise the **East Coast Main Line** as well as foundations of **cycling route 51**, would substantially reduce construction time and engineering cost although suppression of a favourable asset by the construction of the rail route is likely to cause opposition.

- ✓ 5th Studio, despite having the **highest cost** due to tunnel building on steep sections, this route presents the **shortest distance to build** and least impact on the natural capital. This route would disturb far **fewer households** than other routes and **pollute less** due to fewer construction requirements.
- ✓ The three routes will **all pollute in operation**. The longest one, 5th Studio, logically emitting more. However, the amount of daily GHG emissions is lower than car utilisation by about 21 t CO_2e (10,000 trips of 30kms is equal to that of 50km of rail line). The Northern Route proposal, although not the longest, will however affect a greater number of **populated areas**, with the addition of St Neots and Cambourne on the route.
- ✓ 5th Studio's route will have the **least impact on woodlands**. The disturbances created by this route over **fresh water**, the most important of the three options, are negligible due to the scarcity of this land cover.
- ✓ Particular attention has to be set on the East-West Rail route. Indeed, **many woodlands** are affected; this route crosses 1.45ha of **ancient forests**. Also, this route may impact 50% less **agricultural land** than the Northern Route proposal and 30% less than the 5th Studio proposal. Yet, this option would spoil more Grade 1 agricultural land than the other two routes.
- ✓ The Cranfield project team have presented a route that crosses less **Grade 1 agricultural land** and **grassland** than the two other options. However, it crosses many areas with **potential flooding risk**.

9 Site Selection for Natural Capital Investment

Natural capital investment is beneficial to infrastructure service provision and can aid in reducing the costs which rapidly amount with conventional 'grey' infrastructures. Improved aesthetical appearance of infrastructure for society and habitat for biodiversity are always going to be at the pinnacle for mitigating opposition, however, the secondary underlying function of ecosystems services must not be discounted in this day and age especially with the emergence of the UK Greener Future 25 year Environmental Plan (Aldersgate Group, 2017; HM Government, 2018). Natural capital investment is particularly crucial and would benefit from being embedded in decision making processes, particularly through using a net gain approach, such as the one presented in this project, although such an approach can be applicable to any infrastructure project (Aldersgate Group, 2017). DEFRA has awarded Bedfordshire LNPs a grant of £25,000 for developing a Natural Capital Investment Plan for the Oxford-Cambridge Growth Corridor (Bedfordshire Local Nature Partnership, 2017). The following are some suggestions of opportunities for implementing natural capital investment:

9.1 Cambridge Green Belt

Green belts aim to constrain the expansion of urban areas and protect natural habitats. With 73% of residents supporting the designation of green belts such areas appear to present ideal opportunities for expansion and conservation (Campaign to Protect Rural England and Natural England, 2010).

9.2 Designated Sites

Sites of statutory land-based designation such as LNRs and SSSIs provide opportunities for further investment. In total, there are 60 designated sites in Bedfordshire and 127 sites in Cambridgeshire (Campaign to Protect Rural England and Natural England, 2010).

9.3 National Parks

Natural capital investment can also be applied to national and local parks. For those who are likely to be affected by the rail line development it would be suggested by the Cranfield project team that investment should be focused on Bedford Priory

Country Park. Advice could be sought from National Park Authorities (NPA) who are well regarded in the methods of co-operating with partners and organizations to improve and increase the benefits of woodlands in National Parks (National Park Authorities, 2012).

9.4 The Forestry Commission

The Forestry Commission (FC) offer a Woodland Carbon Fund. This presents applicants with opportunities for a grant of capital based on area for the creation of new woodland. To be specific, applicants can get £6,800 per hectare to create new woodlands or if applicants can provide open access to the woodland, they can be eligible for up to £8,500 per hectare (Forestry Commission, 2018a).

There are many other woodland creation and restoration programs run by FC. The Woodland Carbon Fund (WCF) is one of the potential approaches to improve natural capital investment. In addition, the HS2 Woodland Fund, which provides an available reference, was created by HS2 Ltd, providing a grant of £1 million to FC for further management and an additional grant of £5 million to advocate the restoration of existing plantations on ancient woodland sites (PAWS) and creating new woodlands (Forestry Commission, 2018b).

10 Final Thoughts

Through combining an ecosystem services approach with land coverage and land areas, a methodology was produced that provided an interesting set of results for the selection of sites for infrastructure construction. Indeed, the calculations reflected well the impact of different options of rail lines and the consequential impacts on some of Bedfordshire’s and Cambridgeshire’s natural capital assets.

Inspired by ecosystem services analysis, an assessment of land cover has led.to per hectare values which have been emphasised for many natural assets of the area, based notably on their type, location, distinctiveness and condition.

Options of routes were drawn afterwards, to test the calculations and assumptions previously collected, and to give an example of the usage of this natural-capital assessing tool. Important sites (SSSI, LNR, BAP Priority Habitats, WT sites) have been avoided, as well as engineering and terrain requirements added into the balance.

Relevant geographical information systems were then used for calculating the extent of the routes on each land cover type. Those hectares were then multiplied by the ecosystem values previously underlined. Conclusions were drawn following the results.

However, all those conclusions are indicative and do not have to be taken as gospel. The power balance between routes, presented throughout this report seems satisfying enough to be used for decision making, but many criticisms can be raised from the methodology. To be remembered are the following summarised points;

- Route options are bound to change, regarding impact calculations - ancient woodlands may for example be avoided by minor adjustments of routes.
- Different data sets were used for both maps and environmental valuation.
- Assumptions were made and may vary with regard to many factors and sources.

The Cranfield project team sincerely recommends that construction through important sites with statutory land-based designations is avoided, based on the substantial worth of these habitats to biodiversity and the goods and services that are provided by such natural capital.

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