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Fragile monuments of the past

Physical threats and countermeasures

N.W. Willemse

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Author: N.W. Willemse
Authorization: H.F.A Haarhuis
Illustrations: RAAP and the Cultural Heritage Agency of the Netherlands, unless stated otherwise
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Cultural Heritage Agency of the Netherlands
PO Box 1600
3800 BP Amersfoort
www.cultureelerfgoed.nl

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The present publication is intended as a reference work for archaeological heritage professionals who advise landowners, land users or site managers with respect to the care and maintenance of archaeological monuments. This literature study reviews the main physical threats that have the potential to cause damage to archaeological remains present in national monuments. It also answers the question as to what can be done to stop or mitigate these physical threats. As such the report may also be of interest to other individuals involved in the conservation and maintenance of archaeological monuments.

Even when archaeological remains have remained more or less undisturbed in the burial environment, and despite any measures for their protection that may have been taken, they can suddenly be exposed to rapid decay. This decay may result from natural processes, such as increased mineralization, bioturbation, desiccation and erosion, but it can also be due to human action such as agricultural practices, or activities in the built environment. Both human action and natural disturbance have an effect on the preservation of archaeological remains such as flint, bone, metal, wood, ceramics and soil features, and on ecofacts like seeds or pollen. These artefacts and ecofacts and their internal coherence are the main components of what are called 'sites', and they form the main sources of information about the human past. Their (partial) loss is irreversible. However, it is widely acknowledged that not all forms of disturbance or deterioration are equally harmful or will seriously damage a site. Damage is only considered severe when the identity of artefacts, ecofacts or soil features is affected to the extent that their interpretation becomes difficult. This is a situation that should be prevented if possible.

In the Netherlands, damage to an archaeological site is considered critical when research questions at the site level can no longer be answered by archaeological techniques. If a critical loss of information (or a serious threat to that effect) occurs or is expected to occur in the foreseeable future (for example due to desiccation or erosion) protective physical measures are called for. If protective measures are impractical because of costs, technical

challenges or a lack of (local) support, excavation may be necessary to prevent further loss of information.

The risk of disturbance of archaeological remains by human action or natural causes is substantially greater for archaeological remains just below the surface or visible at ground level than it is for those that are deeply covered by sediments. Nearly 55% of the archaeological monuments in the Netherlands are visible at ground level, such as terps and burial mounds. In addition, more than 38% of the monuments contain archaeological remains at shallow depths (within 50 cm -GL). This situation has led to the adoption of a directive for most archaeological monuments which states the maximum allowed cultivation/tillage depths that are still exempt from a legal permit. In its current role as licensing authority the Cultural Heritage Agency of the Netherlands (RCE) is reluctant to allow spatial developments which will affect archaeological monuments.

The data collected for this report also show that the archaeological sites most at risk of irreversible damage are those on arable land, heathland, and in forestry areas. Together, these types of land use account for almost 81% of the surface area of archaeological monuments in the Netherlands. In these terrains the damage often proceeds gradually and without any regulated form of supervision or monitoring. Water management, especially the lowering of (ground)water levels in both rural and urban areas, carries with it a similar risk of gradual degradation of archaeological remains that are vulnerable to desiccation. Other potentially disruptive activities can be expected in the built environment. The current licensing policy for national monuments effectively prevents harmful interventions such as construction work or deeper soil interventions. However, the policy also has some limitations. For instance, natural processes such as desiccation or erosion are not subject to licensing. Furthermore, unlike construction projects the impact of many forms of tillage often exceeds the maximum allowed depth (which is why such activities require prior authorization), but nonetheless in many cases no permit application is filed.

In the context of archaeology-friendly agricultural field management, alternatives to regular cultivation techniques have been proposed, frequently referred to as 'minimal invasive tillage'. These techniques range from completely refraining from any kind of soil intervention ('no tillage') to opting for minimally invasive techniques. Other options are the local exclusion of vulnerable parts of a monument (marked by e.g. fences), switching to extensive grassland management, or transitioning to forms of wetland agriculture in areas that are sensitive to drought. Furthermore, soil compaction and soil disturbance due to heavy traffic and machinery can be avoided by using lighter equipment with low contact pressure, and by accounting for (local) soil conditions.

Physical measures to minimize the risk of desiccation mostly concentrate on increasing soil moisture levels within a specific plot of land. However, raising surface water levels around a site is effective only when this actually improves preservation conditions by creating a higher soil moisture content and a lower oxygen content. To evaluate the measure's effectiveness it is important to also understand the local ground water system. Occasionally trees or shrubs growing on archaeological monuments need to be removed, especially when their presence is or may become harmful to the archaeological remains. Regular (and proper) maintenance prevents the need for more invasive methods of keeping the terrain free from young trees and shrubs. However, vegetation should be removed judiciously and for the purpose of limiting further deterioration. This also applies to

necessary interventions to restore the nutrient balance of grasslands, heathlands and forests on sandy soils.

Finally, sustainable preservation of archaeological monuments *in situ* can be achieved only if and when the different interests and risk factors involved are carefully balanced and when measures taken to counteract adverse processes are appropriate. This requires that all parties concerned mutually understand the different views, wishes and considerations involved and agree on what constitutes an effective measure. While owners of a listed building often take pleasure in their property, the owner/user of an archaeological monument rarely derives any benefits from it. In fact, some protective measures may even lead to a loss of income, for instance when arable land is converted to extensively managed grassland, or when the purchase of new equipment is necessary. In such cases it is appropriate to assess any foreseeable loss of income beforehand and to agree on financial arrangement(s) in relation to the required measures. With regard to archaeological heritage management the fact that different interests are at stake also means that existing paradigms of what is perceived as harmful to archaeological remains should be constantly re-evaluated and if necessary adapted. The present publication aims to contribute to the dissemination and evaluation of this knowledge and to a shared understanding of the conservation problems in relation to archaeological remains.

1 Introduction

1.1 Conservation of archaeological national monuments

Archaeological national monuments are considered to be sites of significant scientific and public interest. The term is almost a hallmark of national heritage: sites containing archaeological remains of such importance as sources of information about our past that they should be preserved for future generations. This is achieved by preserving and protecting the objects, features and archaeological layers present at these sites in the soil rather than by excavating them. This policy of *in situ* preservation is based on the idea that future archaeologists will have access to new techniques and formulate new research questions and so will be able to retrieve much more information from these sources than is possible today.¹ Moreover, the preservation of

visible national monuments such as terps, megaliths or burial mounds is also important because of the significance of these structures as commemorative objects and sources of experience.²

As per 1 January 2020 there were 1,464 archaeological national monuments in the Netherlands. Of these, 1,456 were on dry land (Fig. 1.1), many of them on land owned by larger organizations such as *Staatsbosbeheer* (National Forestry Service) and *Natuurmonumenten* (a major nature conservancy organization), but many others are located on leasehold estates or belong to private owners such as developers or farmers. Only a small proportion are government property. Although owners, leaseholders and managers are encouraged to take the presence of archaeological remains into account they are not legally required to maintain archaeological national monuments.

¹ The European Valletta Treaty encouraged and formalized a policy of *in situ* preservation. In 2007 this finally resulted in the Archaeological Monument Act. See also Willems 2008; Caple 2016.

² Smit *et al.* 2019. The Heritage Act, Section 3.1, mentions both these grounds for listing.

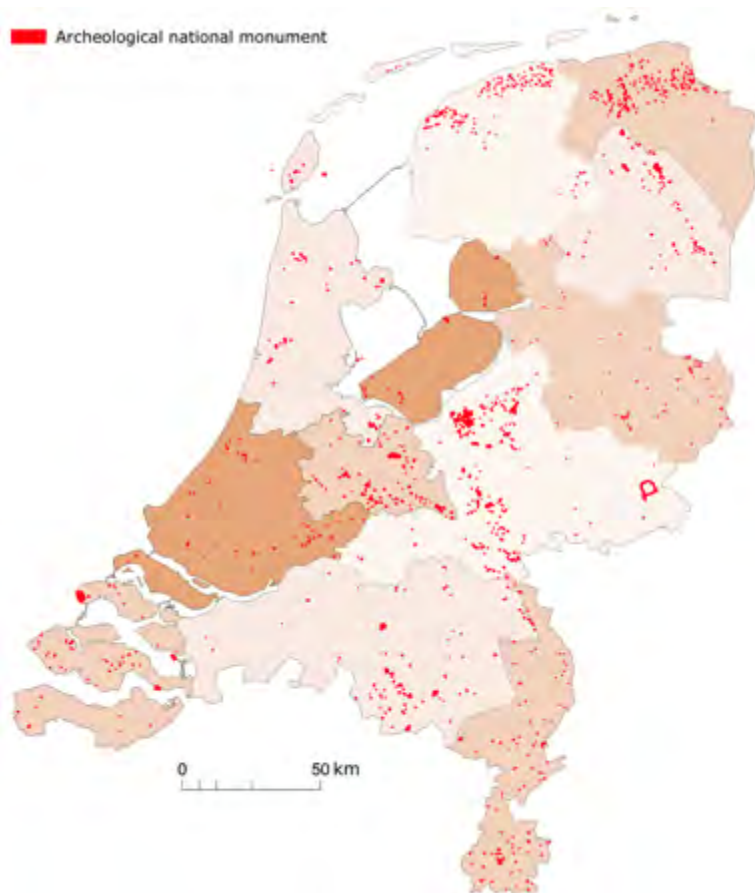


Fig. 1.1 The location of archaeological national monuments in the various Dutch provinces (data source: Cultural Heritage Agency of the Netherlands, situation March 2019).

In many situations, safeguarding archaeology is simply a matter of ‘leaving well alone’. However, sometimes accelerating and more or less visible deterioration threatens to (partly) destroy archaeological remains as sources of information. In these instances conservation measures are called for. For example, when vegetation encroaches upon an archaeological national monument this may result in serious damage to the remains and the information contained in the soil, and a schedule of regular mowing and removal of shoots may be advisable. In the event the effects of regular maintenance are insufficient, physical conservation measures may be required. For example, if archaeological remains are drying out, digging a watercourse around the area to raise the water table may be one possible solution. Occasionally present forms of land use clash with the principle of preservation *in situ*. In these instances landowner(s) will be consulted so as to find other, more suitable forms of usage.

If even these conservation measures prove ineffective to halt the rapid deterioration of archaeological remains, the only options that remain are either to purchase the national monument from the landowner, or to (partly) excavate the site.

Project context

The Dutch State intends to intensify its investment in archaeology in the next few years. The publication ‘Heritage Counts. The Meaning of Heritage for Society’ (Erfgoed telt. De betekenis van erfgoed voor de samenleving.) elaborated on the details of this policy⁴ and listed the three cornerstones of future heritage management:

- 1 The preservation of our heritage for present and future generations;
- 2 The integration of heritage into people’s everyday living space;
- 3 A focus on the connectivity of heritage, i.e. its cohesive and social aspects.

Specifically with respect to archaeology, the first of these cornerstones explicitly refers to the current problems regarding the conservation of the 1,464 archaeological national monuments in the Netherlands.⁵ In the context of its programme Kennis voor Archeologie the Cultural Heritage Agency of the Netherlands addresses these issues in its sub-programme *Instandhouding van archeologische rijksmonumenten* (Conservation of Archaeological National Monuments).⁶ The present study, collecting and disseminating expertise regarding the preservation of archaeological national monuments, is part of the sub-programme.

1.2 Background, goals, and research questions

1.2.1 Background

In recent years several publications have addressed the different types of deterioration of archaeological objects and the various physical measures to slow down or halt these processes.³ These studies focused on the impact of (changes in) the soil environment on the physical condition of soil features and different object categories and materials. Such expertise is crucial for the long-term preservation of the soil archive. However, so far the dissemination of the available expertise and its application to the conservation of archaeological monuments has been limited in the absence of a brief and critical summary of the results of these studies and a review of the existing literature.

1.2.2 Goals

The need for an overview of known physical threats to which archaeological national monuments can be exposed is particularly felt among those who are professionally involved with the conservation of these monuments, and also applies to a summary of the physical conservation measures that could contribute to their *in situ* preservation. At present existing reports on the subject can be difficult to locate, despite the fact that recent years have seen a growing number of studies aiming to generate expertise with regard to conservation. Furthermore, there is not always consensus as to the immediacy of the threats to archaeological national monuments and the different physical conservation measures that could be taken or, for that matter, as to the presumed urgency of some forms of damage. Equally needed is an inventory of the current gaps in our knowledge

³ See for example reviews by Wagner *et al.* 1997; Kars & Kars 2002; Kars & Smit 2003; Klaassen 2005; Louwagie, Noens & Devos 2005; Huisman *et al.* 2006; Kars & Van Heeringen 2008; Huisman *et al.* 2008; Huisman 2009; Minkjan *et al.* 2010; Huisman *et al.* 2011; Van Os & Kosian 2011; Historic England 2016, 2017; Huisman & Van Os 2016; Roorda & Stöver 2016; Historic England 2019; Lascaris 2019; Boosten & Penninkhof 2019.

⁴ cultureelerfgoed.nl/publicaties/publicaties/2018/01/01/erfgoed-telt. The sub-programme ‘Instandhouding van archeologische rijksmonumenten’ was launched in 2018 and will continue into 2021.

⁵ See the RCE’s own website for more information: www.cultureelerfgoed.nl.

⁶ www.cultureelerfgoed.nl/onderwerpen/archeologische-rijksmonumenten/documenten.

of potential physical threats and of conservation measures, so that future research to fill in these gaps can be given priority.

1.2.3 Research questions

The present study focuses on six research questions:

1. What are currently potential threats to the physical condition of land-based archaeological national monuments in the Netherlands, and what impact do these threats have on the archaeological remains?
2. Which are the most immediate threats (as to their impact and frequency) to archaeological national monuments, and what are the causes of these threats?
3. Which archaeological monument categories are the most susceptible or exposed to these immediate threats?
4. Which threats could be halted or prevented by physical interventions, and by which interventions?
5. Which information gaps regarding the harmful consequences of threats cannot be addressed on the basis of current knowledge and require additional study?
6. Which information gaps regarding the effectiveness of physical interventions also require (additional) study?

The present report attempts to answer these research questions by summarizing the results of previous outline studies and monographs, supplemented when necessary with information derived from scientific publications.

1.3 Target audience

This report primarily aims at professionals involved in archaeological monument conservation who have to advise landowners, users and/or caretakers on archaeological monument conservation, or when development and maintenance briefs have to be drafted. The report also serves as a reference publication for those interested in or actively involved in

archaeological national monument conservation. There is a need among heritage professionals and caretakers of archaeological national monuments for a summary of known risk situations as well as potential physical countermeasures to cope with those risks. Such measures may be part of a regular maintenance regime but also be integrated into the monument's development and layout.

1.4 Guidelines

Together the seven chapters of this report review the known (potential) physical threats to archaeological national monuments as well as possible countermeasures. The current chapter outlines the goals of this study and provides some background. The second chapter presents a brief outline of the currently listed archaeological monuments in the Netherlands, their physical manifestation and landscape setting, and how their national protection has been given shape. The third chapter explains the concepts of physical threat, vulnerability, damage, and loss of information, while the chapters four and five address the actual physical threats in the form of natural processes (Ch. 4) and human actions (Ch. 5).

Chapter 6 discusses concrete physical measures landowners and land users can take to prevent or halt damage to archaeological national monuments. These measures can be an integral component of the development of a monument or they may be part of a regular maintenance regime. The latter option is cursorily discussed and gives only an indication of the possibilities.⁷ Finally, the concluding chapter discusses which physical risk factors pose a potential threat to land-based archaeological national monuments, which of these are the most prominent, and which monument categories are most at risk.

⁷ See also 'Handboek Cultuurhistorisch Beheer' (Baas & Raap 2010), and various publications by Probos (Jansen & Van Benthem 2005; Boosten, Jansen & Van Benthem 2011; Boosten & Penninkhof 2019).



Fig. 1.2 Megalith D45, Emmerdennen (National Monument No. 45.374).

1.5 Credits and acknowledgements

This report was commissioned by the Cultural Heritage Agency of the Netherlands. A number of individuals contributed to the issues and sources mentioned. We are particularly grateful to Huub Scholte Lubberink, Theo ten Anscher, Reinier Ellenkamp (RAAP), Maarten Wispelwey (Regio Noord Veluwe) and Carla Soonius (Archeologie West-Friesland).

Several persons at the Cultural Heritage Agency of the Netherlands participated in the discussions, or in the course of the project collected data and case studies which have been included in the current text. We owe a special word of thanks to the supervisory committee: Iepie Roorda, Guido Mauro, Fred Brounen, Hans Huisman, and Bertil van Os. It is they who introduced the necessary nuances with respect to the physical threats to archaeological national monuments, and they also provided a workable definition of the concept of damage. Unless stated otherwise the texts in this report were written by Nico Willemse, who also functioned as project leader on behalf of RAAP.

2 Archaeological national monuments *in context*

2.1 The current list of scheduled sites.

The first archaeological national monuments in the Netherlands were listed under the Monument Act of 1967. By 1 January 2020 their number had increased to 1,464 of which 1,456 were land-based (Fig. 2.1). Each of these monuments occupies one or more scheduled properties. Some monuments are vast, comprising several complex types and/or complexes (Table 2.1) which may be visible on the surface (burial mounds or prehistoric raised field boundaries, the so-called Celtic fields) or invisible below ground (house plans, urn fields).⁸ Many monuments are rather small; over one half occupy one hectare or less (Fig. 2.2). As of March 2019 archaeological national monuments represented well over 1,800 scheduled properties and more than 4,100 complexes. In 2019, land-based archaeological monuments occupied almost 7,675ha of which 31.2% were situated in the province of Gelderland (Fig. 2.1), followed by the provinces of Zeeland (13.4%), Utrecht (10.5%) and Noord-Brabant (10.2%).

Table 2.1 The number of archaeological complexes per national monument.

Number	%
1	51.2
2	22.0
3	10.7
4	4.7
5	1.7
> 5 (max. 124)	9.7
Total	100

The majority of archaeological national monuments can be found in the provinces of Gelderland (294) and Groningen (215), while Flevoland has the fewest (27). The differences can be explained by looking at the formation of the current list and the principles which guided it.⁹ Initially the emphasis was firmly on the protection of visible archaeological remains. For instance, the national monument list for the provinces of Groningen and Friesland includes many terps while the large number of

archaeological monuments in the province of Gelderland (294) is in part a reflection of the many burial mounds in this province. Flevoland on the other hand has had a comparatively short research history and this province's archaeological remains tend to be deeply buried, with the exception of maritime wrecks and the archaeological monuments on the World Heritage Site of Schokland.

Also in the province Zuid Holland, few areas (56) are scheduled as archaeological national monument, even though the rather intense building activity in this province (housing developments, infrastructure) has revealed many sites. Perhaps Zuid Holland's high population density and intense competition for available space are responsible for the small number of monuments.

⁸ A site is defined by its complex type or types (e.g. settlement, burial ground) and the approximate date of each complex (e.g. Neolithic, medieval).
⁹ Van Haaff 2006. See also Van Doesburg & Stöver 2018.

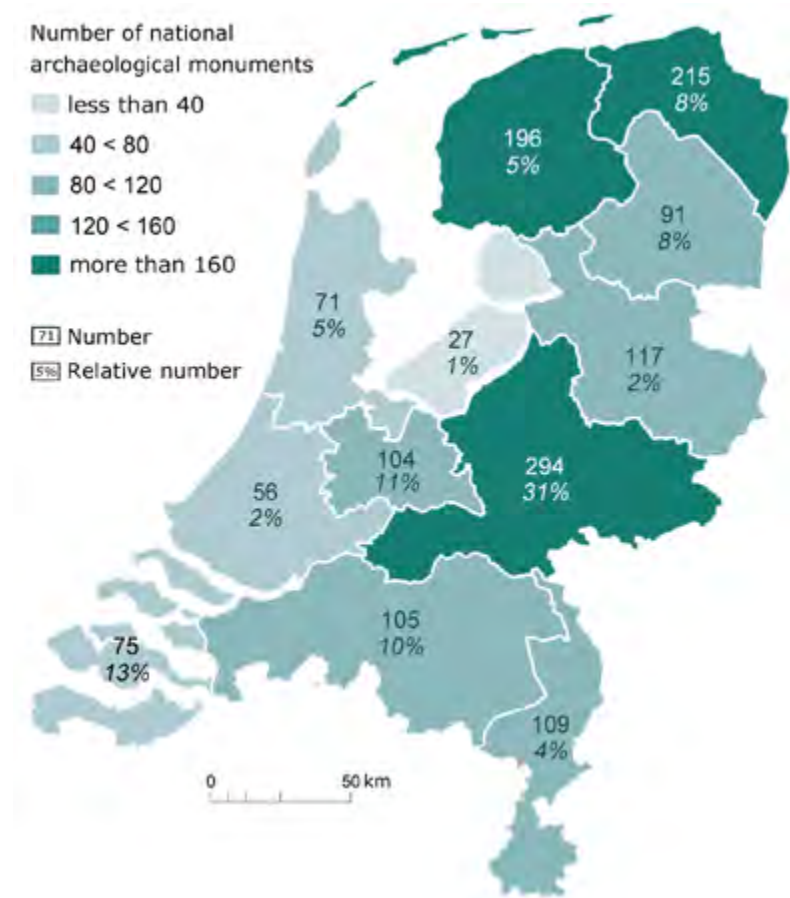
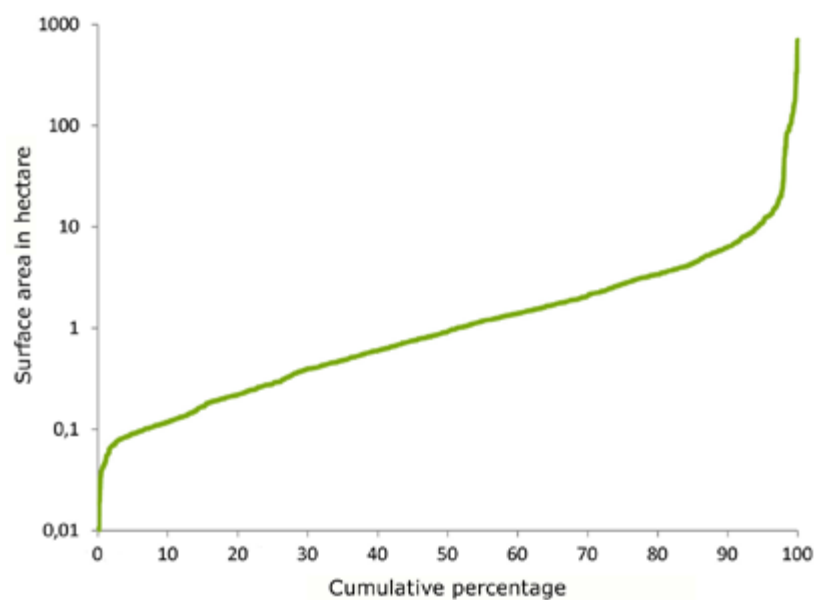


Fig. 2.1 Distribution of the number of archaeological national monuments and their relative size (in percentages) per province.



Another noticeable feature of the current national monument list is the significant variability in the number of scheduled archaeological complexes per complex type (Table 2.2).¹⁰ The current list of nationally scheduled complexes is dominated by burial mounds (57%). At the other extreme, the list includes only two cult sites and one dike. Other complex types which seldom feature on the list are quarry sites, agricultural features, Celtic fields, sites relating to shipping traffic and infrastructure, house mounds, towns/villages, sconces, and rural defensive systems.

Fig. 2.2 Surface distribution of the archaeological national monuments.

Table 2.2 Scheduled complex types (national monuments).

Complex type	Complexes	
	Frequency	%
Burial mound	2.328	56,7
Settlement (including defensive)	368	9,0
Terp	353	8,6
House mound	208	5,1
Moated site	139	3,4
Urn field	72	1,8
Church	46	1,1
(Roman) Villa	33	0,8
Castle	67	1,6
Motte and bailey	64	1,6
Megalithic tomb	57	1,4
Monastery	49	1,2
Road	29	0,7
Burial ground (indeterminate)	28	0,7
Military camp	21	0,5
Shipping	19	0,5
Cemetery	17	0,4
Burial	16	0,4
Other complex types	205	5,0
Total	4.119	100

¹⁰ See also Zoetbrood et al. 2006.

Since a few decades archaeological national monuments are no longer scheduled individually but only in the context of scheduling programmes (*aanwijzingsprogramma's*).¹¹ The purpose of this policy change was to schedule especially sites with complex types and/or dates that are under-represented on the current list. The ultimate goal is a national list of scheduled archaeological monuments which accurately reflects the settlement history of the Netherlands.

2.2 Current land use

The condition of subsurface archaeological objects and features depends to a significant degree on the usage of the land that contains them. Particularly studies in other countries than the Netherlands have revealed that archaeological sites under arable fields and commercially exploited forests are especially at risk.¹² The threat to grassland sites (occasional ploughing, tractor traffic, and manuring) is less severe.¹³ The increasing urbanization of the landscape in which archaeological monuments

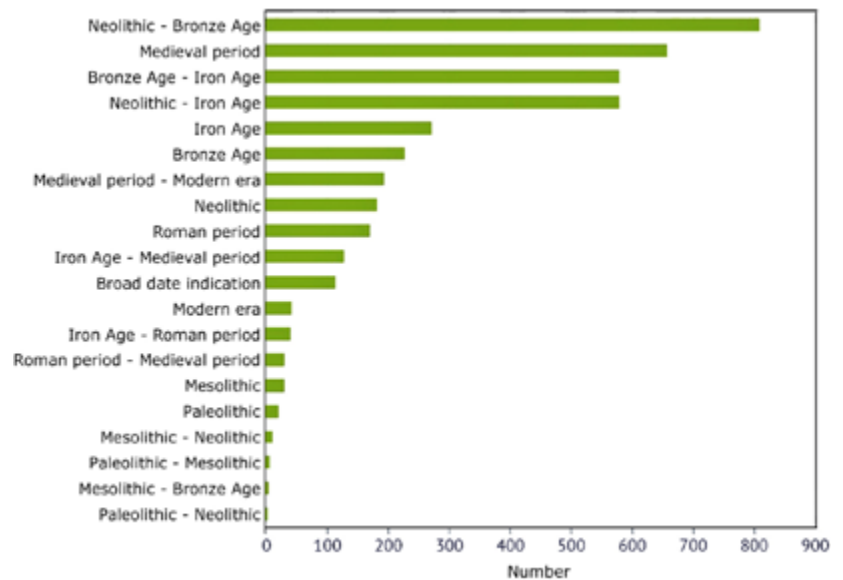


Fig. 2.3 The number of scheduled archaeological complexes per period (situation October 2019).

can be found is another risk factor, mainly because of building activities and the construction of infrastructure on and below the surface.¹⁴

- ¹¹ *Beleidsregel aanwijzing beschermde monumenten 2009* (built and archaeological monuments) and 2013. See also Bazelmans *et al.* 2008; Smit *et al.* 2013.
- ¹² Prickett 1985; Darvill & Fulton 1998; Crow & Moffat 2004, 2005; Trow & Holyoak 2008; English Heritage 2010; Datema 2015.
- ¹³ Darvill & Fulton 1998.
- ¹⁴ Huisman *et al.* 2011a; Huisman 2013. See for instance also Van Doesburg & Stöver 2018.



Fig. 2.4 Burial mound. Kampsheide, Balloo.

In 2018 most of the land that was part of archaeological national monuments was grassland (36.6%), followed by nature areas (woodland and sand drifts 30.3%, heath 4.9%), and arable (9.1%) (Fig. 2.5; data supplied by the Dutch Cadastral Service).¹⁵ Nearly 22ha was built up, more than one third of it (7.2ha) situated on scheduled terps (Fig. 2.7). The character of these built-up areas ranged from a historical village centre, often comprised of a few houses with or without a church, to farmsteads with their access roads. In the latter case the main threats were digging activities associated with the construction or demolition of residential and farm buildings, manure pits, wind turbines, and utilities trenches on and around the farmyard.¹⁶

The most common form of land use on and near the other visible archaeological national monuments was forestry (53.1%), followed by heath (28.2%) and grassland (9.3%) (Fig. 2.7). A few areas were situated underwater, such as a large part of the ‘drowned’ town of Reimerswaal (National Monument Register 532.468). From the 11th/12th to the 16th century AD this was the third largest town in the province of Zeeland. During exceptionally low tides it is sometimes still possible to see the remnants of Reimerswaal on the bottom of Oosterschelde/Bergsche Diep.

2.3 Visible and invisible scheduled monuments

2.3.1 Covered or exposed?

The conservation and decay of subsurface archaeological features depend on many different factors, such as subsurface depth, groundwater levels and oxygen levels, and to some extent also soil chemistry (buffer capacity, chloride content).¹⁷ Over the centuries some scheduled sites have become buried under clay, peat or sand and are today to be found at depths of over a metre. Other sites have little or no soil cover and are just below the surface.

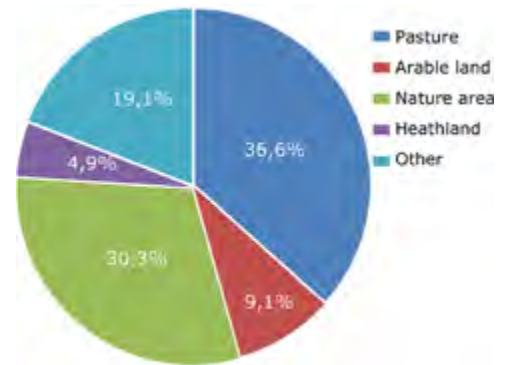


Fig. 2.5 The most common forms of land use on archaeological national monuments; situation 1 January 2018.

The shallower the depth of features, layers and objects, the more exposed they are to various human activities and natural processes. Most types of physical decay proceed from the surface downward (agricultural tillage, earthworks, vegetation management, erosion). This means that sites near the surface or at shallow depths are much more vulnerable than those that are deeply buried.

The archaeological sites and areas that are most at risk at the moment are those on the surface and at shallow depths (terps, burial mounds, Celtic fields, mottes, (ring)forts), all the more so as together they represent almost 75% of the total number of scheduled complex types. In fact, at many scheduled monuments archaeological remains occur both on and (deeply) below the surface, as for instance in the case of the lowest strata and immediate surroundings of terps (Fig. 2.10) and burial mounds.

Only a few archaeological monuments are covered by thick sediments. Even in Holocene deposits many monuments are situated near the surface at a depth where groundwater levels may fluctuate.¹⁸ These sites are sensitive to desiccation and ongoing changes in soil humidity.¹⁹

¹⁵ Data on scheduled monuments supplied by the Cultural Heritage Agency of the Netherlands, 30 September 2019; on land use: TOP10NL, Kadaster 2018.

¹⁶ Van Doesburg & Stöver 2018.

¹⁷ Huisman 2009.

¹⁸ Van Heeringen & Theunissen 2007.

¹⁹ E.g. Van Heeringen & Theunissen 2006; 2007.

2.3.2 Subsurface depth of archaeological remains

Sometimes the information that is currently available is insufficient to be able to determine the exact location and subsurface depth of the archaeological layers in a national monument.²⁰ It is usually easy to establish the location of visible complexes in the field, but locating non-visible complexes can be difficult. This poses no serious problem in areas with little variation in soil type or in the subsurface depth of archaeological remains. However, at a site with many different soil types or an uneven surface, not knowing the exact location is problematic.

Exempted maximum depths for different types of soil interventions have been specified for many archaeological monuments (Fig. 2.12).²¹ Usually the exempted zone extends down to the top of the archaeological level and as such is an indication of the depth of the archaeological strata.²²



Fig. 2.6 Land use per 1 January 2018 on the Ezinge terp (National Monument 522.164).

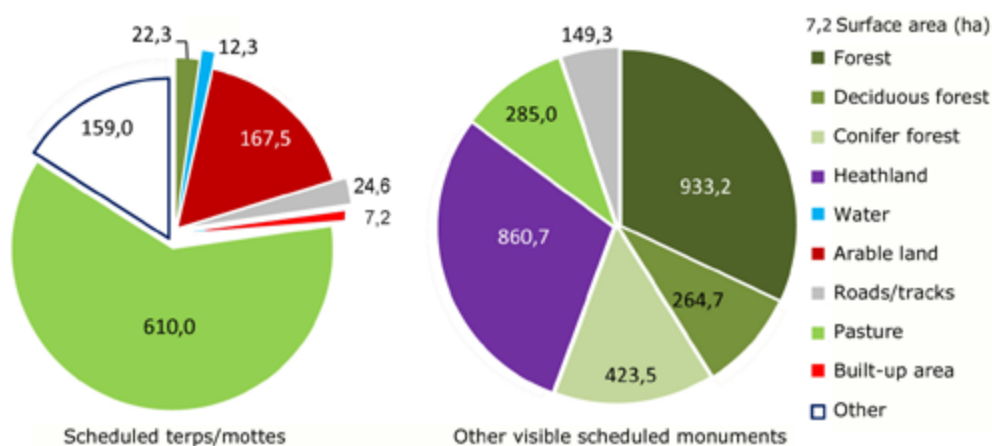


Fig. 2.7 Land use on scheduled terps/mottes and on the category 'other visible scheduled monuments'; situation 1 January 2018.

²⁰ For c. 96% of all archaeological monuments the level at which archaeological layers begin is known, but not how deep they extend.

²¹ Information on exempted maximum depths is based on 2005 data in the AMK archive. Since 2005, 51 more national monuments have been scheduled; maximum exempted depths have also been specified for those. However, this information cannot easily be accessed digitally. In the Table, post-2005 data are indicated as 'indeterminate' or 'indeterminate: visible'.

²² Iepie Roorda (RCE), oral communication (October 2019).

Table 2.3 Maximum exempted depths for terps/mottes.

Exempted depth	Surface	
cm -GL	ha	%
0	40,1	3,9
10	15,1	1,5
20	47	4,6
15	13,5	1,3
25	31,9	3,1
25/60	18,0	1,8
30	235,8	23,1
30/40	11,0	1,1
30/60	66,4	6,5
35	20,5	2
40	160,6	15,8
40/60	60,3	5,9
60	43,5	4,3
Indeterminate, visible	175,7	17,3
Other	63,1	6,2
Indeterminate	15,8	1,6
Total	1.018,7	100

In many cases scheduling procedures and specifications of a maximum exempted depth allowed for current forms of land use.²³ As a result, the exempted depths of 3% of the scheduled monuments are a combination of, say, 60cm for building plots and 30cm for surrounding agricultural land (Table 2.3). These are not included in Figure 2.12. Especially terps combine sections of grassland, arable, farmyard and built-up areas, and exempted depths for agricultural land around the terps are also generous, for the same reason. On the other hand, exempted depths for other types of (vacant) visible archaeological monuments are zero whenever possible (Table 2.4).

Table 2.4 Exempted depths visible monuments.

Exempted depth	Surface	
cm -GL	ha	%
0	2.310,2	74,3
>0 <35	44,4	1,4
> 35	9,2	0,3
Indeterminate, visible	638,6	20,5
Indeterminate	108,2	3,5
Total	3.162	100

2.4 Maintenance and policy

Both the Heritage Act and the Monument Act state that a monument cannot be altered, damaged, or endangered without a permit (Section 2.5).²⁴ However, there is no legal obligation to maintain a monument. Maintenance in this context means keeping archaeological monuments in good condition so as to preserve their information value, and in the case of visible monuments also their experience value. Many individuals are involved in maintenance on a regular basis: farmers and foresters, caretakers of nature preserves, contract workers and contractors, builders, supervisors, amateur archaeologists, and volunteers engaged in nature conservancy. However, none of them are official caretakers of archaeological remains, and most private landowners feel no responsibility to maintain 'their' scheduled monument. Few of them apply to the *Subsidieregeling Instandhouding Monumenten* (SIM; 'Monument Maintenance Subsidy Fund') for maintenance subsidy.²⁵

The Amersfoort-based Cultural Heritage Agency of the Netherlands (RCE) is responsible for scheduling, permits, and enforcement as an executive body representing the Minister of Education, Culture & Science (OCW).²⁶ Other persons involved in administration and policy making may also come into contact with archaeological monuments: provincial, municipal or waterboard administrators and others working for the public sector.

²³ Until the 1990s, no Guidelines for Permit Exemptions document was issued for newly scheduled national monuments. Exempted depths for activities on those monuments were decided later, in the context of the AMK project.

²⁴ Permit requirements are listed in Section 11 of the 1988 Monument Act, today part of the transitional provisions included in the Heritage Act.

²⁵ Grontmij 2015, 50; Smit *et al.* 2019, 19.

²⁶ The Inspectorate for Information and Heritage (*Inspectie Informatievoorziening en Erfgoed*) is charged with the supervision of archaeological national monuments.



Fig. 2.8 Ringfort Hunneschans; Uddel, province of Gelderland (National Monument 527.251).



Fig. 2.9 Motte; Veere (National Monument 550.474).

The national policy on the management of archaeological national monuments deviates substantially in several aspects from municipal/provincial policy with respect to archaeological areas protected under zoning regulations.²⁷ First, interventions on national monuments are subject to a separate permit procedure (Section 2.5); the introduction of the Environmental Act (*Omgevingswet*) will not change this. Second, in the case of archaeological national monuments the emphasis is on sustainable maintenance/subsurface preservation. Third, with respect to allowing spatial development, the Cultural Heritage Agency of the Netherlands in its present role as licencing body is more strict than local governments. Interventions will be permitted only if they do not damage the archaeological remains. Heritage aspects take precedence over other interests, and if disturbance is unavoidable any archaeological research that is to be carried out has to conform to stringent requirements.

On the other hand, in areas protected under zoning regulations municipal administrations usually opt for 'archaeo-friendly' building, integration, and/or preservation *ex situ* (i.e. archaeological excavation and recording).²⁸ Here, interventions are allowed in principle provided any archaeological remains are handled properly, with preservation *ex situ* being an acceptable option. In these cases, heritage value has to compete with a range of other interests.

2.5 Interventions subject to a permit

In the case of archaeological national monuments, interventions that are potentially harmful to the archaeological remains and features and/or that would disfigure the monument are subject to a permit.²⁹ This legal requirement is an important tool to prevent or limit harmful activities on scheduled national monuments.³⁰ Those who wish to carry out such activities have to file an application for a monument permit with the Minister of Education, Culture and Science. The subsequent procedure includes an assessment whether the proposed intervention is a) potentially harmful or disfiguring; b) necessary; and c) could be made less disruptive or disfiguring by altering

the plans. Based on the outcome of the assessment a decision will be made as to whether the permit will be issued, and under what conditions.³¹

The Cultural Heritage Agency of the Netherlands may issue a case-specific Guideline for Permit Exemptions, which explains in more detail the scope of the permit requirements in relation to the scheduled monument. A Guideline also states the depth below the surface above which interventions do not need a permit (the exempted depth), and also which interventions always require one. Surface exemption limits do not apply to scheduled national monuments, whereas they do apply to areas protected under zoning regulations.

As a rule, the exempted depth for an archaeological national monument will be stated in its scheduling document, but this may also be postponed until a permit application is filed for alterations to the monument. A permit exemption is a written document by which the Minister sanctions certain activities that disturb the soil (down to the stipulated exempted depth) even without a monument permit. This frees land users from the obligation of having to apply for a permit for every alteration to the monument (as per Section 11 of the 1988 Monument Act), even those that do not impinge upon the archaeological remains.

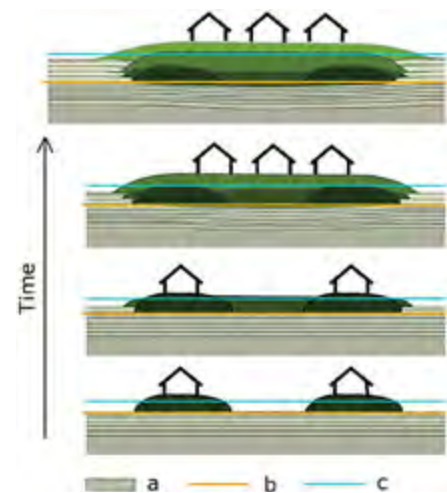


Fig. 2.10 Schematic cross section of various stages in the development of a terp. Not to scale (after Nieuwhof & Vos 2018). a: Salt marsh deposits; b: Horizontal plane c: Maximum flood level

²⁷ Smit *et al.* 2019, 10.

²⁸ Ibid.

²⁹ Permit requirements are laid down in Section 11 of the 1988 Monument Act, today part of the transitional provisions included in the Heritage Act. The monument permit is scheduled to be abolished and replaced by an environmental permit once the Environmental Act (*Omgevingswet*) comes into force. At the same time municipalities will become licencing bodies (for multiple interventions) with the Cultural Heritage Agency of the Netherlands serving in an advisory capacity. The Agency will have the right to grant or withhold its consent to the Council's proposal.

³⁰ See for example Van Doesburg & Stöver 2018, 56-58.

³¹ Cultural Heritage Agency of the Netherlands 2012a 'Behandelen vergunningaanvragen archeologische monumenten' ('Procedure Permit Applications Archaeological Monuments'). The introduction of the Environmental Act (*Omgevingswet*) will replace this permit policy by a formalized legal norm stating the assessment criteria for activities on archaeological national monuments that are subject to a permit.



Fig. 2.11 An example of an archaeological national monument covered by Holocene deposits is the De Hooge Weere polder, Aartswoud (National Monument 531.042). Aerial photograph, 1984 (IPP – Willy de Vries-Metz). Detail: schematic cross-section of the monument (Van Heeringen & Theunissen 2006; 2007).

Certain interventions always require a permit even when they do not disturb the soil, or stay above the exempted depth. Examples are construction activities; raising, lowering or levelling the surface; paving over (sections of) public space; and filling in water courses.

2.6 Permit applications

Every year dozens of archaeological national monuments are the object of one or more permit applications filed with the Cultural Heritage Agency of the Netherlands (Fig. 2.13).³² Roughly two thirds of these applications concern infrastructural projects and demolition or construction activities. Of the remainder, many

applications are for activities relating to the consolidation, restoration or maintenance and development of archaeological national monuments.

Groningen and Friesland, the two provinces that contribute a significant number of national monuments to the list, are also responsible for a matching number of permit applications (Fig. 2.14), but the interventions in question tend to involve fairly small areas. In these provinces more than half the permit applications for activities on archaeological national monuments involve terps, house mounds, or settlement areas. Many of the applications for terps are for building permits. Another substantial proportion of applications concerns activities involving burial mounds, usually consolidation.³³

³² See also *Erfgoedbalans 2009* (Beukers 2009, 78).

³³ Beukers 2009.

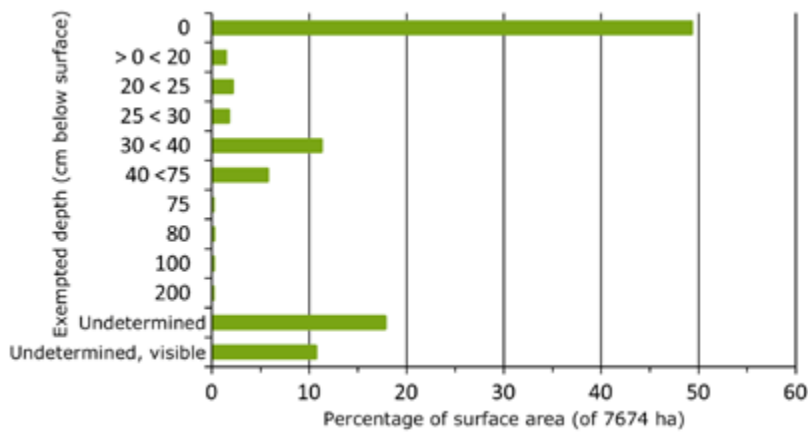


Fig. 2.12 Several exempted depths can be specified for one single scheduled monument, but each cadastral property can have only one exempted depth. Figure 2.12 shows the exempted depths that apply to 97% of the total area occupied by a scheduled national monument (based on the AMR archive, Cultural Heritage Agency of the Netherlands).

The 2009 report *Erfgoedbalans* already concluded that most of the applications concern national monuments in built-up or agricultural areas. This is hardly surprising, since construction activities tend to be concentrated in those areas. In the province of Zuid-Holland, for example, national monuments are under considerable pressure. Although the province

has relatively few national monuments, many of them are in urban areas. The large number of applications in agricultural areas are probably mostly related to farm extensions (new barns and byres), new housing developments and business parks; agricultural activities generate few applications.

Some intervention types are (virtually) absent from the list, such as utility trenches (e.g. fibre-optics) or pipelines. Particularly conspicuous is the absence of activities relating to water management. Activities relating to drainage to lower the water table are exempt because they take place outside archaeological national monuments. However, lower water tables can have a significant impact on the condition of uncharred subsurface organic remains and may also lead to soil compaction (Section 5.4.7).³⁴ Interestingly, hardly any permit applications involve earth tillage-related activities in agricultural areas, such as reversal ploughing, field drainage, or conversion of grassland into arable. Many forms of regular agricultural usage (limited to the plough soil, i.e. 30-40cm) are exempt but interventions at deeper levels do require a permit. Examples are the use of heavy equipment to deepen the plough soil and break through the plough pan; drainage activities; or tree planting.

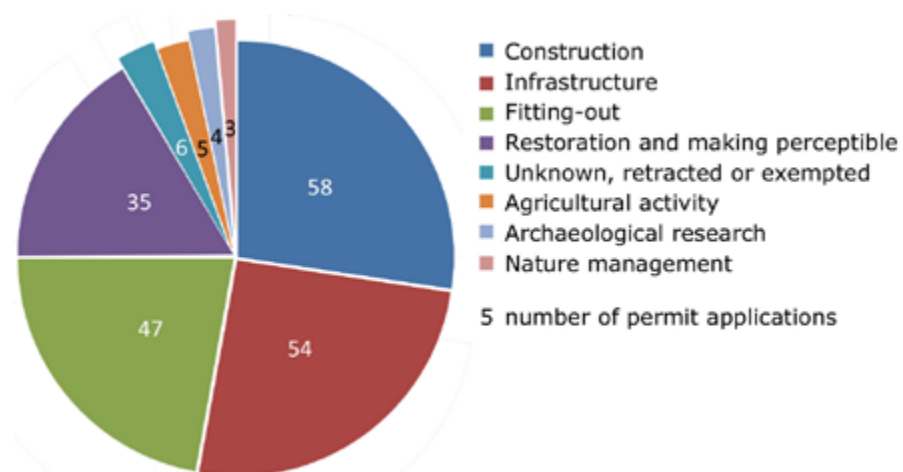


Fig. 2.13 Diagram showing the types and numbers of interventions on scheduled archaeological national monuments for which permit applications were filed in the years 2013-2017.

³⁴ Only interventions within the boundaries of an archaeological national monument are subject to a permit. This includes groundwater extraction by means of local wells.

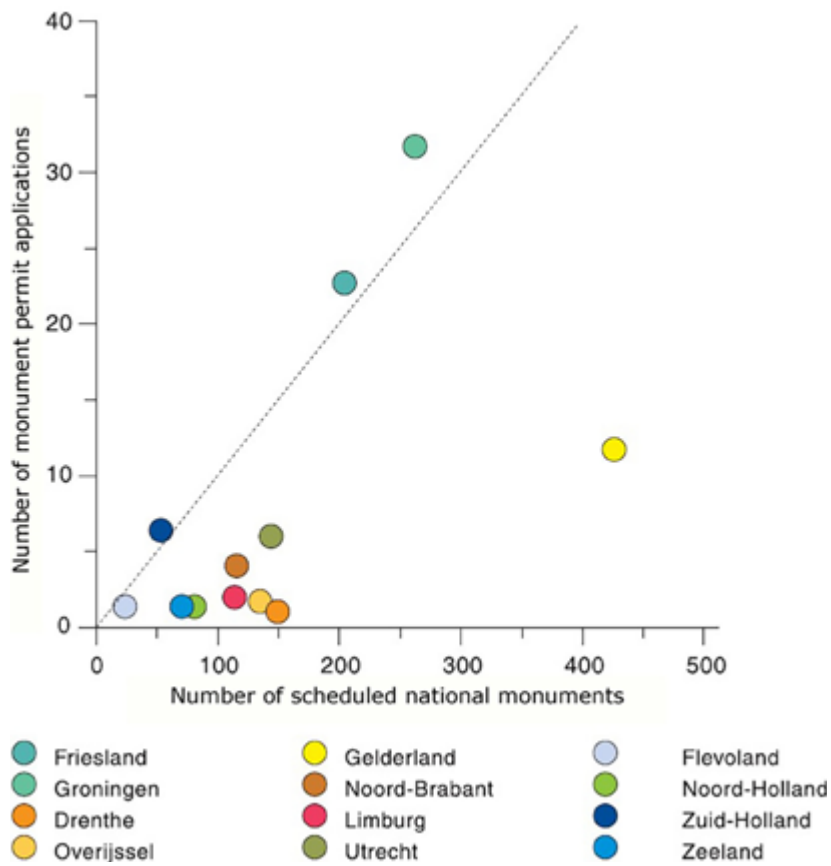


Fig. 2.14 Number of monument permit applications per province until 2009, plotted against the number of scheduled national monuments per province (image courtesy of Beukers 2009, 80).

3 The vulnerability of archaeological national monuments

3.1 The conservation principle

Preservation *in situ* of archaeological remains is the core principle of Dutch policy and legislation, based on the premise that preservation today will benefit future research into the past. The development of new techniques will enable future generations to extract more information from the national soil archive than we are capable of today.³⁵ Moreover, those future generations may want to ask different questions. In other words, information value, or the significance of a national monument as a source of knowledge about the past, is not a constant and may (or may not) increase through time.³⁶

The information value of a site is lost when finds, features and deposits diminish in size and quality as a result of the decay of (large sections of) the site. In cases where this decrease in information value threatens to exceed a possible increase, it stands to reason that measures must be taken to stop or at least slow down any

further deterioration. Archaeological excavation of (parts of) the site is another option. Figure 3.1 shows the theoretical increase and decrease in information value for a random site as lines plotted against the factor time. Here the relationship is linear, but in fact an increase in the information value of a site is more likely to proceed in leaps and bounds as a result of new techniques or new research questions.

Hypothetical information value increases are hard to predict in the reality. We are more familiar, at least in theoretical terms, with a value decrease. Archaeological remains below the surface are constantly subjected to processes of decay, and in time the potential information they contain becomes less (Chapter 4).³⁷ Perhaps burrowing rabbits, badgers and wild boar cause some local damage to a burial mound.³⁸ Or the buried, waterlogged organic remains in a polder may dry out and start to degrade when the water table is lowered.³⁹ There are many other possible scenarios for degradation which all ultimately lead to a loss of information.

3.2 What constitutes a physical threat?

Information sources contained in the archaeological soil archive comprise objects, soil features, soil deposits and any ecological remains they may contain, and last but not least the associations between all of them. If the recognizability and quality of these remains and features, their significance, or their mutual relations are lost, information is lost. This is usually a very gradual process of decay and deterioration.⁴⁰ There are even situations in which degradation almost comes to a stop, which is why even very early archaeological remains are sometimes relatively well preserved. However, when soil conditions change the slow decay process can quickly accelerate, and the site as a source of information can be (partly) lost within one or two generations (Fig. 3.2).

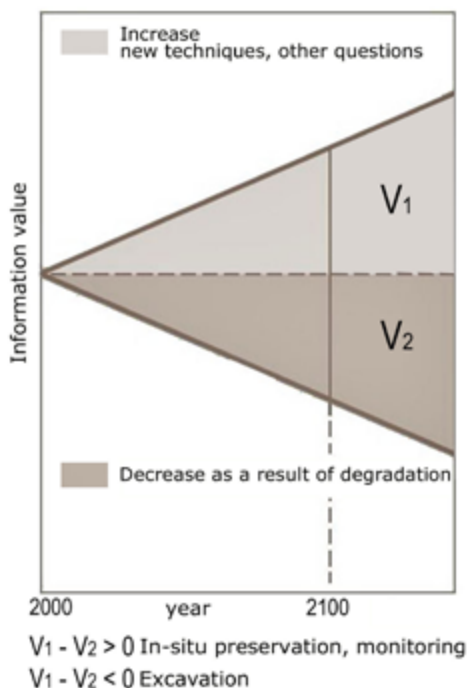


Fig. 3.1 Theoretical changes in the information value of a hypothetical archaeological site through time (after Van den Berg *et al.* 2010).

³⁵ Willems 2008; Caple 2016. For examples see Reich 2018 with regard to human bone DNA.

³⁶ Directoraat-Generaal Cultuur en Media (Directorate-general Culture and Media) 2017; Smit *et al.* 2019. Information value can also decrease when it becomes apparent that more sites of a specific complex type exist than was initially thought (and therefore that they are not particularly rare).

³⁷ Huisman 2009; Huisman & Van Os 2016.

³⁸ E.g. Datema 2015.

³⁹ E.g. Van Heeringen, van Kregten & Roorda 2003; Van Heeringen & Theunissen 2007.

⁴⁰ Greathouse *et al.* 1954; Schiffer 1996, 141-261.

Alternatively, sweeping but episodic processes such as field erosion on a slope during a downpour, forest trees blown over during a storm, accidentally ploughing too deep, burrowing by wild animals or human vandals, each constitute a threat and in some instances can be directly harmful. Physical threats to archaeological national monuments can therefore be natural (Chapter 4) as well as anthropogenic (Chapter 5). Both types can potentially cause a quite rapid decay of archaeological remains. The following are some examples of actions that may cause physical damage:

- Agricultural activities (e.g. to remove hardpan, improve drainage, or levelling), activities relating to nature conservancy (sod removal, vegetation control), or intensive recreation;
- Building activities, infrastructural or development projects in the built environment;
- Changes in groundwater tables and groundwater levels. Fragile archaeological remains such as wood and bone which have long been preserved under anaerobic or poorly oxygenated conditions can start to decay when the groundwater table is lowered and the remains become accessible to fungi and/or other soil organisms;
- Erosion (slope, wind), especially on arable fields;
- Plant roots and disturbance by burrowing mammals and subsurface organisms;
- Illegal human activities that are harmful to the monument, such as illegal digging or illegal metal detection (which may selectively deplete site data), or vandalism.

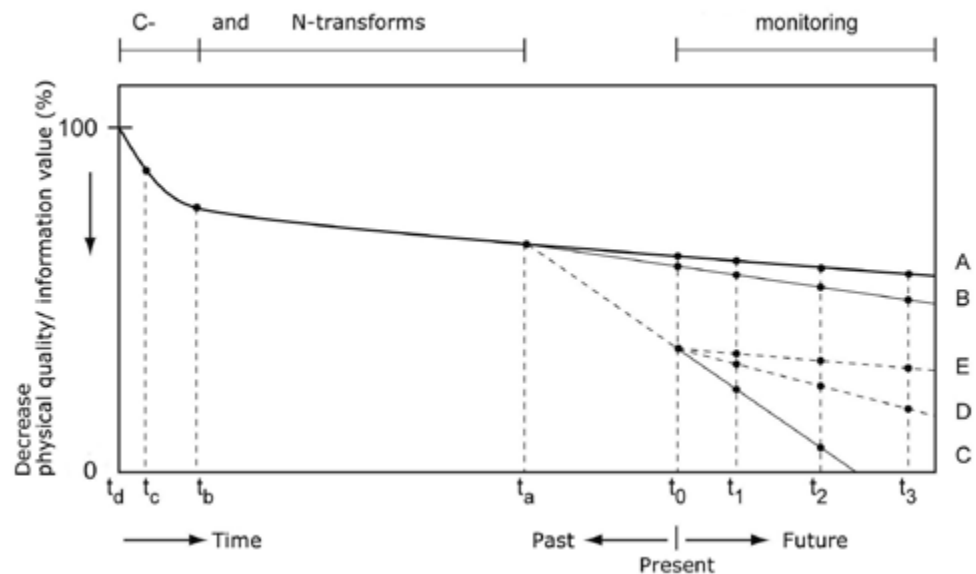


Fig. 3.2 Loss of information value of an archaeological site through time. t_d =Time of site deposition/formation; t_c =Time of intensive occupation of the site; t_b =Time of burial in the soil. C transformations = Cultural changes which affect the site; N transformations = natural changes. A = State of equilibrium during which loss of information is slow. BCDE = Outcomes of the different forms of accelerated decay starting at different times. t_a =Time when new threats start to increase. t_0 - t_3 =monitoring episodes (image courtesy of Leidraad Standaard Archeologische Monitoring ("Guideline Standard Archaeological Monitoring") version 1.0).

3.3 Immediate or gradual deterioration

Besides this distinction between active interventions and natural causes another possible distinction is that between immediate and gradual deterioration.⁴¹ The term immediate deterioration refers to processes or activities that have an immediate impact on archaeological remains, such as tillage (ploughing, harrowing, harvesting, sowing), removing hardpan, levelling, soil removal on behalf of building and construction projects, soil erosion, burrowing by wild animals or people. In places where these harmful activities penetrate deep into the soil they may also initiate barely perceptible forms of decay. This is what is meant by gradual degradation.⁴²

Gradual degradation is often an unintended side effect of changes in agricultural land use or in urban/rural water management,⁴³ but it can also occur during regular forms of use. In the low-lying, wetter parts of the Netherlands uncharred organic remains are often well preserved, but lowering the water table can start a process of desiccation and subsequent decay (Section 5.4.7).⁴⁴ Gradual degradation may also begin when grassland is converted into arable (which requires more intensive and deeper tillage), or when fields are drained (which enables the use of heavier machinery). Other factors indirectly responsible for gradual degradation are cutting or removing the turf, and scraping off and redepositing the top layers. If repeated on a regular basis all these activities may result in the gradual removal of the archaeological levels.

The forms of gradual degradation listed above occur throughout the Netherlands. However, their impact is more difficult to establish than those of immediate threats. Ultimately, the effects of gradual degradation can be as devastating as those of immediate degradation, if not more so. Gradual degradation is probably most common in areas where archaeological remains are covered by a cultural layer (plaggen soil, raised fields), a permanent vegetation cover, fluvial sediment, dunes, peat, or other Holocene deposits.

3.4 When does a loss of information occur?

Degradation is defined as a decrease in the recognizability and association of soil features, objects or layers in (part of) a monument due to either interventions or natural processes (Fig. 3.2).⁴⁵ In other words, degradation equals a loss of information or information sources on our past.⁴⁶ Degradation happens at different scales: that of the individual object/feature (highly localized disturbance), the individual complex (site-wide disturbance of the property) or the entire landscape (for example due to desiccation). Degradation also takes place at different degrees of intensity and can be associated with different types of damage. Many natural processes (e.g. bioturbation, treading and trampling, weathering, podzolization), while damaging the soil archive, have been going on for centuries, well before the archaeological site was discovered and scheduled. As for human activities, some areas have been under cultivation and been trodden and trampled by cattle and people for centuries; in those locations the soil and its archaeological remains have already to some degree been affected.⁴⁷ Disturbance caused by bioturbation or compaction by no means always implies that an archaeological national monument has been damaged. The concepts of damage and information loss must therefore be defined more precisely before they can be applied successfully.

In the context of this publication, damage is defined as a situation in which the physical condition of the archaeological remains in (a section of) a scheduled monument is deteriorating. Damage can result in a loss of information if the recognizability of information carriers (features, layers, objects), their significance, or their association are lost so that research questions at the level of the scheduled complex can no longer be answered. Information loss is therefore a serious consequence of damage, and whenever it occurs (or is about to occur), physical protective measures to prevent further deterioration are crucial.

⁴¹ Vos & Van der Vliet 2006; Van Os & Kosian 2011.

⁴² Ibid.

⁴³ Willemse 2017.

⁴⁴ Ibid.

⁴⁵ Huisman & Van Os 2016.

⁴⁶ See for example Van den Berg *et al.* 2010, 162; Van Os & Kosian 2011; Huisman & Van Os 2016.

⁴⁷ See for example Huisman & Ngan-Tillard 2019.

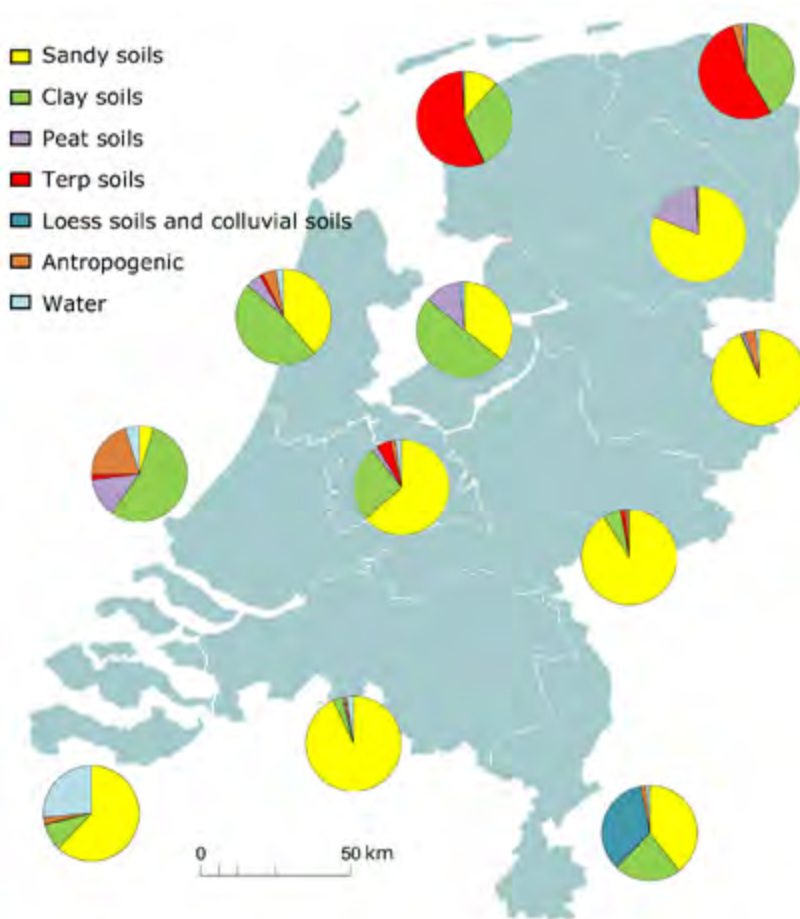


Fig. 3.3 Prevailing soil types at archaeological national monuments per province, by surface (data source: *Bodemkaart van Nederland* (Soil Map of the Netherlands) 1:50,000/NEBO50, PEDOK version 2018).

Not all forms of soil disturbance constitute damage that should be prevented or stopped. Damage can assume various shapes and degrees of severity. It can be local (e.g. tree fall, Section 4.2.5; or burrowing animals, Section 4.2.3), or affect several areas simultaneously (e.g. soil erosion). Some forms of damage happen suddenly (e.g. a collapsing slope) while others arise gradually (e.g. desiccation). Monitoring is an important instrument to ascertain whether or not damage is imminent. If it is, the expected impact on a scheduled monument may be such that intervention to prevent further deterioration is unavoidable. In the event

physical protective measures are undesirable or impractical, *ex situ* preservation can be an alternative solution so as to prevent ongoing information loss.

If on the other hand the deterioration progresses very slowly and the resulting damage is imperceptible or cannot be measured, no immediate action is needed. Instead, regular monitoring of the monument is recommended until the loss of information will have reached a critical point, at which time a decision will have to be made as to whether mitigating measures or (partial) excavation of the complex are necessary.

3.5 Monument type and vulnerability

The extent to which ploughing or natural processes such as soil erosion are harmful to the information value of an archaeological monument depends not only on the scale and speed of the deterioration but also on the specific nature of the archaeology and on local soil conditions (Fig. 3.3). Variables such as subsurface depth, material type, feature density, groundwater table, sloping terrain, or land use give a global indication of which forms of physical threat can be expected. In general, especially the following variables increase the risk of damage to a site:⁴⁸

- Limited subsurface depth of the archaeological remains. The shallower their depth, the more vulnerable the site;
- High feature/object density, in the form of horizontal (in the plane) or vertical (stratigraphic) concentrations of archaeological features and/or objects;
- The presence of uncharred organic materials such as wood, textile, leather, bone, and seeds;
- Soil types that are sensitive to compaction, particularly waterlogged (clay or peat) soils with archaeological layers, constructions, features or objects that are easily compressed.

⁴⁸ Roorda & Stöver 2016.

3.5.1 Subsurface depth and groundwater conditions

Many of the variables listed above are not mentioned in the available documentation on archaeological monuments and have to be reconstructed on the basis of other sources. These variables are therefore useless for an estimate of the number of at-risk sites on the current national monument list. As an alternative, we therefore used GIS for information on the dominant soil types and forms of land use for each cadastral plot in each archaeological national monument.⁴⁹ These data were combined with the exempted depths provided by the Cultural Heritage Agency of the Netherlands so as to estimate the top levels of archaeological layers. The following data sources were consulted:

- Monument documentation (Monument register, reference date October 2019);
- Complex type (Cultural Heritage Agency of the Netherlands, ARCHIS, version April 2019);
- Exempted depths (Cultural Heritage Agency of the Netherlands/AMR data 2005);
- Land use and surface (TOP10NL, versions 2016 and 2018);
- Soil type and soil subtype (NEBO50);
- Groundwater stage (NEBO50).

The complex types have been subdivided into non-visible and visible complexes. Another subdivision is based on the approximate groundwater situation at the top of the archaeological remains at archaeological national monuments. This subdivision uses the classification scheme for groundwater stages of the current version of the *Nederlandse Bodemkaart* (Soil Map of the Netherlands), scale 1:50,000.⁵⁰ This classification is based on the average range of the highest and lowest groundwater level relative to the surface and recorded over a number of years (Table 3.1). However, the groundwater stage classification currently in use no longer reflects the present situation. Groundwater tables have changed since the initial field surveys of the 1950s and 60s due to a series of factors.⁵¹ When the present study was in preparation only the update for the groundwater stage map for the low-lying sections (i.e. mainly

the west and north) of the Netherlands had been completed; the publication (digitally, via PDOK) of the results of the most recent groundwater dynamics survey for the higher sections of the country (i.e. mainly east, centre and south) was still in preparation.⁵² Figure 3.4 therefore shows the overall groundwater situation for the present archaeological national monuments on the basis of these older data.

Table 3.1 Groundwater stage classification.

Groundwater stage	HGW (cm -GL)	LGW (cm -GL)
Ia	< 25	< 50
Ic	> 25	< 50
IIa	< 25	50-80
IIb	25-40	50-80
IIc	> 40	50-80
IIIa	< 25	80-120
IIIb	25-40	80-120
IVu	40-80	80-120
IVc	> 80	80-120
Va	< 25	> 120
Vao	< 25	120-180
Vad	< 25	> 180
Vb	25-40	> 120
Vbo	25-40	120-180
Vbd	25-40	> 180
VI	40-80	> 120
Vio	40-80	120-180
VId	40-80	> 180
VII	80-140	> 120
VIIo	80-140	120-180
VIIId	80-140	> 180
VIII	> 140	> 120
VIIIo	> 140	120-180
VIIIId	> 140	> 180

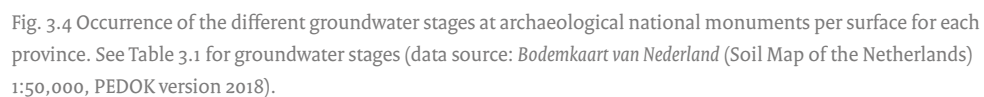
Table 3.1 Groundwater stages in the Netherlands, showing Average Highest Groundwater levels (HGW) and Average Lowest Groundwater levels (LGW) (data source: Knotters *et al.* 2018).

⁴⁹ The data, soil polygons, and cadastral information derive from the *Nederlandse Bodemkaart* (Soil Map of the Netherlands), scale 1:50,000 (current PDOK version) and from the Cadastral Service's digital topographic reference database, TOP10NL (version 2018).

⁵⁰ Published as a geo-dataset at www.pdok.nl.

⁵¹ Knotters & Janssen 2005; *Werkgroep achtergrondverlaging* NHV 2016.

⁵² Knotters *et al.* 2018.



3.5.2 Classification of monuments

Combining these data and allocating the monuments to different categories allows us to arrive at a general overview of the subsurface depth (Fig. 3.6) and groundwater situation of archaeological national monuments (Fig. 3.4, Table 3.2). In Table 3.2 the largest category of visible archaeological complex types in the scheduled monument database has been split into two sub-categories, T and Z. House mounds, terps and mottes are category T, the other types of visible archaeological landmarks are category Z. In both categories, archaeological remains are visible on the surface which renders them particularly vulnerable to both immediate and gradual forms of deterioration. The reason house mounds, terps and mottes have been treated as a separate category is that preservation conditions for organic remains and other materials in their deposits can be exceptionally good.

Non-visible archaeological complexes have been subdivided based on the Average Highest/Lowest Groundwater level at the site (Categories A, B or C).

Category A1: Sites with archaeological levels at a subsurface depth of less than 50cm and (usually) above Average Highest Groundwater level or HGW (groundwater stages VI and higher). In this situation most degradation processes are mechanical (fragmentation, mixing) and aerobic (Section 4.3).

Category A2: Sites with archaeological levels at a subsurface depth of less than 50cm but with lowest groundwater levels fluctuating above and below the archaeology (groundwater stages I, II, III). Preservation in relatively wet conditions. Due to the shallow depth mechanical processes are the most influential while the occasionally capillary nature of the soil favours both aerobic and anaerobic degradation processes (Fig. 5.22).

Table 3.2 Classification of archaeological national monuments based on subsurface depth and groundwater situation.

Category	Context	Groundwater stage	Description context
Z/T	Visible	Does not apply	Visible landmarks (e.g. burial mounds, terps, earthen banks, Celtic Fields)
A1	↑ 50 ↑ HGW	V and higher	Archaeological remains/archaeological levels present at a subsurface depth of no more than 50cm and above Average Highest Groundwater level (HGW). Here, degradation processes are mainly mechanical and aerobic.
A2	↑ 50 ↑ LGW	I (II) (III)	Archaeological remains/archaeological levels at a subsurface depth of no more than 50cm and above Average Lowest Groundwater level (LGW). Here, degradation processes are mainly mechanical and aerobic as well as anaerobic.
B	↓ 50 GHW-LGW	(II) III IV V VI	Archaeological remains/archaeological levels present at a subsurface depth of more than 50cm and between GHW and LGW. Here, degradation processes are aerobic as well as anaerobic.
C	↓ 50 ↓ LGW (red)	I (II)	Archaeological remains/archaeological levels present at a subsurface depth of more than 50cm and below LGW. In the absence of oxygen and other oxidizing agents (sulphate, iron, manganese) reducing conditions are common.
W	W	Not applicable	Archaeological remains in bottom sediments of freshwater bodies, where oxidation and reduction are the most important processes.



Fig. 3.5 Late Neolithic trackway through the peat, Bourtangerveen. The trackway was constructed around 2550BC by Beaker Culture farmers. The road surface consisted of c. 3m-long logs – some of them split – of alder, birch, lime, oak, and maple. The trackway has been scheduled since 1981 (National Monument 45.391). Following a lowering of the groundwater table sections the monument appeared to be at risk from desiccation, but in 2008 and 2018 fungi-related damage proved to be limited.⁵³ More or less constant waterlogging of the peat soil matrix and the wood itself have created anaerobic conditions. The oxygen content of waterlogged wood is zero due to bacterial action (Photo: Geheugen van Drenthe/Casparie *et al.* 2004).

Complex types where archaeological levels are at a subsurface depth of more than 50cm are less vulnerable to mechanical degradation. Complex types where archaeological levels lie between the Average Highest and Lowest Groundwater table have been classified as B

(groundwater stages II, III, IV, V en VI). A good example of B sites are monuments where archaeological levels are covered by an anthropogenic mineral-rich humic layer (old cultivated soils, the so-called plaggic and hortic anthrosols) of at least 50cm.⁵⁴

Category B: Sites covered by Holocene deposits of at least 50cm (marine and fluvial clays, peat, dune sand) but (temporarily) above Lowest Average Groundwater level (Fig. 3.5). Uncharred organic remains but also metals are at risk of being affected by aerobic processes and occasionally (waterlogged and non-consolidated soils) also by compaction, settling and/or shrinkage.⁵⁵

Category C: land-based complex types which are not reached by most forms of regular soil-based activities (e.g. tillage, nature management, superficial interventions in the built environment) and which lie entirely below Average Lowest Groundwater level. In peat or clay deposits, anaerobic conditions prevail.⁵⁶ Examples of monuments with preservation conditions below groundwater level are the Neolithic and Early Bronze Age site Spijkenisse-Hekelingen I in Polder Vriesland, and the recently reburied Roman vessel De Meern 4 at Leidsche Rijn (Veldhuijzen-De Balijs).⁵⁷ Other examples are the archaeological monuments Laag Dalem-Gorinchem (Dalemse Donk, National Monument 531.041), the Neolithic site of Koedood, Barendrecht (National Monument 529.084), and the site Liewegje/Zuiderpolder, Haarlem (National Monument 532.446).

Figure 3.6 shows the location of archaeological national monuments in the Netherlands grouped by subsurface depth and groundwater situation. Visible archaeological national monuments (Categories Z and T) are responsible for 54% of the total surface of the national archaeological soil archive. At 13%, house mounds, terps and mottes (category T) form a minority (Table 3.3). The most important category by far (A1: 34%) are the non-visible sites which lie at shallow subsurface depths under mostly dry conditions.

⁵³ Huisman & Theunissen 2008; Huisman (RCE), oral communication.

⁵⁴ De Bakker & Schelling 1989; Doesburg *et al.* 2007.

⁵⁵ Corrosion may or may not occur, depending on the type of metal and the soil type.

⁵⁶ Caple & Dungworth 1996; Huisman *et al.* 2008; Historic England 2018.

⁵⁷ National Monuments 45.987 and 531.057, respectively; De Groot & Morel 2007.

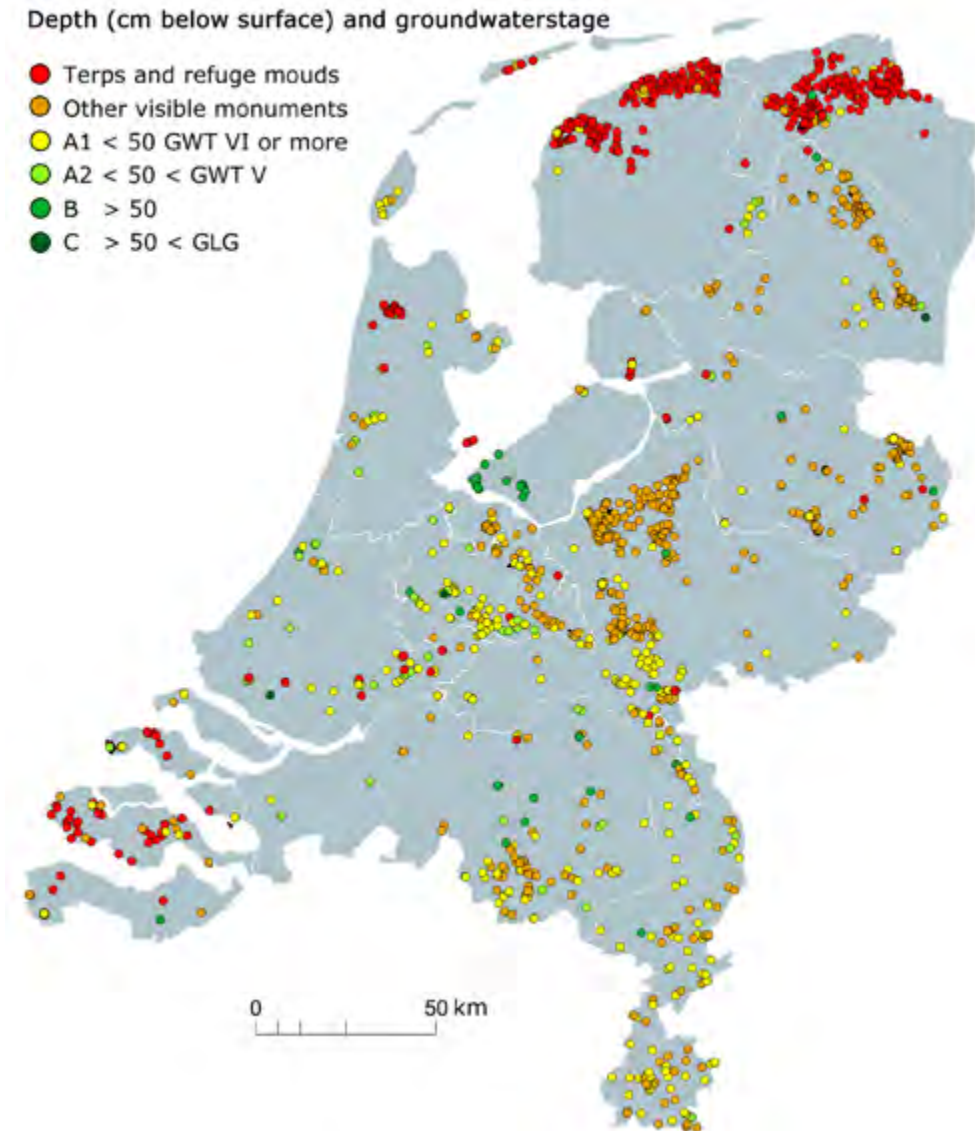


Fig. 3.6 Location of archaeological national monuments by subsurface depth and groundwater situation

Especially deeply buried (subsurface depth >50 cm) 'wetland sites' situated below Average Lowest Groundwater level (Category C) are poorly represented on the current list of archaeological national monuments. Because of their relatively shallow depths and their groundwater situation most scheduled sites in the west of the country that can be classified as wetland sites fall into categories A2 and B (Fig. 3.6).⁵⁸ At many of these sites only archaeological remains in the deeper levels are more or less constantly waterlogged. The 2009 report *Erfgoedbalans* stated that 13% of the archaeological sites known at that time were

situated in areas with high groundwater levels (groundwater stages I-II, Average Highest Groundwater level < 40cm below the surface) and c. 43% in areas with moderately high groundwater levels.⁵⁹ As a rule, Category C complex types are only discovered in the context of spatial development projects. In some cases the Cultural Heritage Agency of the Netherlands, municipalities and project developers have been able in concert to come to a solution whereby sites of this type could be spared and scheduled. Sites where this was the case since 2005 include Gorinchem-Dalemse Donk, Barendrecht-Koedood (Albrandswaard), Haarlem-Liewegje, and Kijfhoek-Heerjansdam.

⁵⁸ Van Heeringen & Theunissen 2001a; Van Heeringen & Theunissen 2002; Van Heeringen, Smit & Theunissen 2004; Theunissen & Van Heeringen 2006a.

⁵⁹ Beukers 2009.

Table 3.3 Proportional distribution of the different categories.

Category	Surface in hectares	
	ha	%
Visible, other	3.071,1	41,2
Terp/motte	991,4	13,3
A1	2526,9	33,9
A2	320,6	4,3
B	342,9	4,6
C	7,5	0,1
W	193,9	2,6
Total	7.454	100

3.6 Erosion and decay

Weathering, erosion and decay

All objects and features near or below the surface will be affected and disintegrate after a shorter or longer period of time under the influence of the atmosphere, water, soil erosion and sedimentation, and organisms; human action falls into the latter category. These processes are called weathering, although the term degradation is used for the disintegration and decay of anthropogenic materials.⁶⁰ In general, three types of erosion are distinguished:⁶¹

1 Mechanical or physical weathering

The term mechanical weathering refers to processes in which the mineral or chemical composition of features, layers or objects does not change. Mechanical weathering is the product of the relocation or transportation of soil material by (soil) erosion, anthropogenic soil disruption, breakage due to strain, and bioturbation (by plants or animals). These factors result in the disturbance of features or contexts, and the fragmentation (or even disintegration) of materials.⁶²

2 Biological weathering

Micro-organisms and other soil organisms play an important part in the transformation and (by implication) decay of uncharred organic

materials. Responsible for the conversion of vegetable and animal matter into humus are soil mesofauna (such as worms or insects) and microfauna as well as microflora. Microfauna comprises aerobic soil bacteria, actinobacteria, and fungi.⁶³ In the presence of sufficient oxygen in the soil these micro-organisms can literally eat their way through organic materials such as botanical remains, wood, and bone (Section 4.3.2).⁶⁴ However, several inorganic materials can also be affected by microbiological weathering by fungi and bacteria.⁶⁵

3 Chemical weathering

The term chemical weathering refers to the corrosion and gradual dissolution of the original objects or materials into the soil.⁶⁶ Several different agents are involved in this process which affects subsurface archaeological remains, including redox reactions, soil acidity, and soil salinity.

These three mechanisms – mechanical, biological, and chemical weathering – affect organic materials derived from plants and animals (bone, wood, leather, textile, seeds, or pollen) but also inorganic materials in archaeological contexts, such as metals, glass, stone, flint, and pottery.⁶⁷ The speed and impact of each of these processes and the effect they have on each other depend on the type of material, environmental variables such as soil conditions (lithology, groundwater levels, soil biotope conditions), subsurface depth, and time. When these processes of decay slow down an apparently stable equilibrium is reached between the archaeological remains and the surrounding soil matrix. It is this apparent equilibrium that allows us to retrieve information from the soil archive even after (sometimes) millennia. This applies to all types of information carriers in the soil: soil features and layers which owe their visibility to the presence of (in)organic compounds attached to the soil particles; artefacts, and all other remains that are associated with human activity in the past, such as those left behind by human consumption or other use of plants or animals, constructions, or flint assemblages.

⁶⁰ Huisman 2009.

⁶¹ Meeussen *et al.* 1997; Schiffer 1996; Louwagie, Noens & Devos 2005; Huisman 2009.

⁶² Huisman *et al.* 2011a; Reuler *et al.* 2014; Lascaris 2019.

⁶³ Locher & De Bakker 1990; Chapin, Matson & Mooney 2002.

⁶⁴ The effects of micro-organisms on wood and bone (animal and human) have been studied in detail; see Klaassen 2005, 2007; Jans 2005, 2008; Huisman 2009; Kendall *et al.* 2018.

⁶⁵ Klaassen, Eaton & Lamersdorf 2008.

⁶⁶ French 2003; Huisman 2009; Karkanas 2010.

⁶⁷ Huisman (2009) discussed the processes which affect archaeological materials and features at great length, and they are therefore dealt with only briefly in this report.

Degradation in detail

Since the 1990s heritage institutions throughout north-western Europe have been acknowledging the danger that our archaeological heritage may be disappearing at an accelerating rate. This awareness has resulted in the Valletta Treaty which in turn has influenced national legislation. The Treaty has also been instrumental in initiating a number of EU-funded research programmes which are focusing on the processes responsible for the decay of subsurface archaeological materials such as metal, bone, and wood.⁶⁸ Furthermore, in the last twenty years a number of international congresses addressed the preservation of subsurface archaeological remains.⁶⁹

Today the mechanisms behind the degradation of most archaeological materials are fairly well understood although some material categories have been studied more thoroughly (bone, wood) than others (metals, soil features, soil strata).⁷⁰ One important conclusion is that different materials and features respond differently to changing soil conditions. (Ground)water situation and soil stability in particular are important factors in the preservation of archaeological heritage; in most cases changes will disrupt an existing state of dynamic equilibrium, with an accelerating degradation of the archaeological soil archive as a result.⁷¹

Oxidation and reduction

Soils or soil strata which are not waterlogged during at least part of the year are usually well oxygenated. Soil minerals are the most important source of this oxygen. Oxygen constitutes half of the mass of silicon dioxide (silica, SiO₂), for example. In well aerated soils this is supplemented by the inexhaustible supply of oxygen from the atmosphere.⁷² Metal and other materials tend to corrode more quickly in soils that contain oxygen.⁷³ The presence of oxygen also has a negative impact on uncharred organic material, since oxygen is the main factor in their mineralization by aerobic soil organisms (Section 4.3).⁷⁴

Structural water loss, especially by lowering the groundwater table, exposes inorganic as well as uncharred organic remains to oxidation processes and the activity of soil organisms.

Conversely, reducing conditions favour the preservation of uncharred organic materials, because biological degradation (almost) stops.⁷⁵ Reducing conditions are often created in oxygen-free environments. The level from where the soil becomes anaerobic depends on the extent to which it is waterlogged and on the intensity of microbial activity.⁷⁶

Acidity

Soil acidification is a product of the emission of nitrogenous substances, such as nitrogen oxides (NO_x) and ammonium (NH₃), and sulphur dioxide (SO₂). In the atmosphere these substances react and are converted into others including nitric acid (HNO₃) and sulphuric acid (H₂SO₄), which together in turn react with ammonium to form ammonium sulphates and ammonium nitrates. The latter two substances are present in the atmosphere as aerosols (atmospheric particulates). Upon being deposited on the surface or in water all these substances can cause acidification and thus contribute to the degradation of both ecosystems and materials. Whether or not a soil will acidify largely depends on its buffer capacity (i.e. its capacity to neutralize acids), which in turn is dependent on the presence of either calcium carbonate (in lime soils) or alkaline cations (Ca, Mg, K, Na) and other metal ions (Fe, Al) (present in clay or organic materials).⁷⁷

In (natural) calcium-rich soils archaeological remains will not be affected by acidification because the calcium functions as a buffering agent. Acidification will start once the buffer capacity is diminished (or never existed in the first place). This is most likely to happen in poor sandy soils with a heathland or dune vegetation. Soil acidity influences the preservation of bone, metal and textile; however, in archaeological monuments on poor sandy soils all organic remains that were not charred will already have disappeared long ago.⁷⁸

A low Ph will slow down the activities of many soil animals.⁷⁹ For instance earth worms become noticeably less active if the soil Ph drops below 7.⁸⁰

⁶⁸ Wagner *et al.* 1997; Kars & Kars 2002; Klaassen 2005/Klaassen *et al.* 2008, respectively.

⁶⁹ Corfield *et al.* 1998; Nixon 2004; Kars & Van Heeringen 2008; Strætkvern & Huisman 2009; Matthiessen & Gregory 2012; Leuzinger *et al.* 2016.

⁷⁰ Huisman 2009.

⁷¹ Huisman & Van Os 2016.

⁷² Chapin, Matson & Mooney 2002.

⁷³ Scully 1990; James & Bartlett 2000; Schüring *et al.* 2004; Smit, Van Heeringen & Theunissen 2006; Huisman 2009, Chapters 3 and 5-8.

⁷⁴ Huisman 2009.

⁷⁵ Klaassen 2005; Huisman 2009; Dousterelo, Goulder & Lillie 2010.

⁷⁶ James & Bartlett 2000.

⁷⁷ CBS, PBL, RIVM, WUR 2019.

⁷⁸ Huisman 2009, Chapters 3 and 5-8.

⁷⁹ Ibid.

⁸⁰ Edward & Lofly 1972; Meeussen *et al.* 1997.



Fig. 4.1 Soil wash on a maize field in hilly terrain (photo: Geelen 2006).

4.1 Introduction

This chapter focuses primarily on natural factors which in theory might damage archaeological national monuments. Virtually any material on or just below the surface will eventually deteriorate and disintegrate under the influence of the atmosphere, erosion, and animal activity.⁸¹ Most of these ‘natural’ processes are very slow to act and are part of the intrinsic mechanisms of weathering, decomposition and decay which affect all surface and subsurface matter (Section 3.6).⁸² However, some natural processes operate much more quickly and could potentially cause damage quite rapidly. Examples are soil erosion, accelerated decomposition and deterioration (within a few years) of organic materials that are no longer waterlogged, or the fading of soil features due to chemical reduction processes.⁸³ Rampant growth of (invasive) vegetation, intensive grazing by livestock and/or wild animals, and burrowing by for example rabbits, badgers and wild boar are all examples of natural risk factors in relation to archaeological national monuments.

4.2 Surface processes

4.2.1 Soil erosion

Soil erosion affects the surface itself as soil material is washed or blown.⁸⁴ There are also other forms of erosion, such as adhering soil (tare weight soil) that is removed during the harvesting of root vegetables or tubers,⁸⁵ or the soil that is washed out of burrows by horizontal seepage. Slope cultivation also frequently causes soil material to slide downslope; this is called tillage erosion.⁸⁶

Erosion by running (rain) water typically occurs on slopes with a 2% inclination or steeper; level areas tend to be little affected by it. On fallow fields and on soils where precipitation cannot easily penetrate (clay, loam) a severe downpour can cause surface run-off and rill formation (Fig. 4.1).⁸⁷ Steep earthen

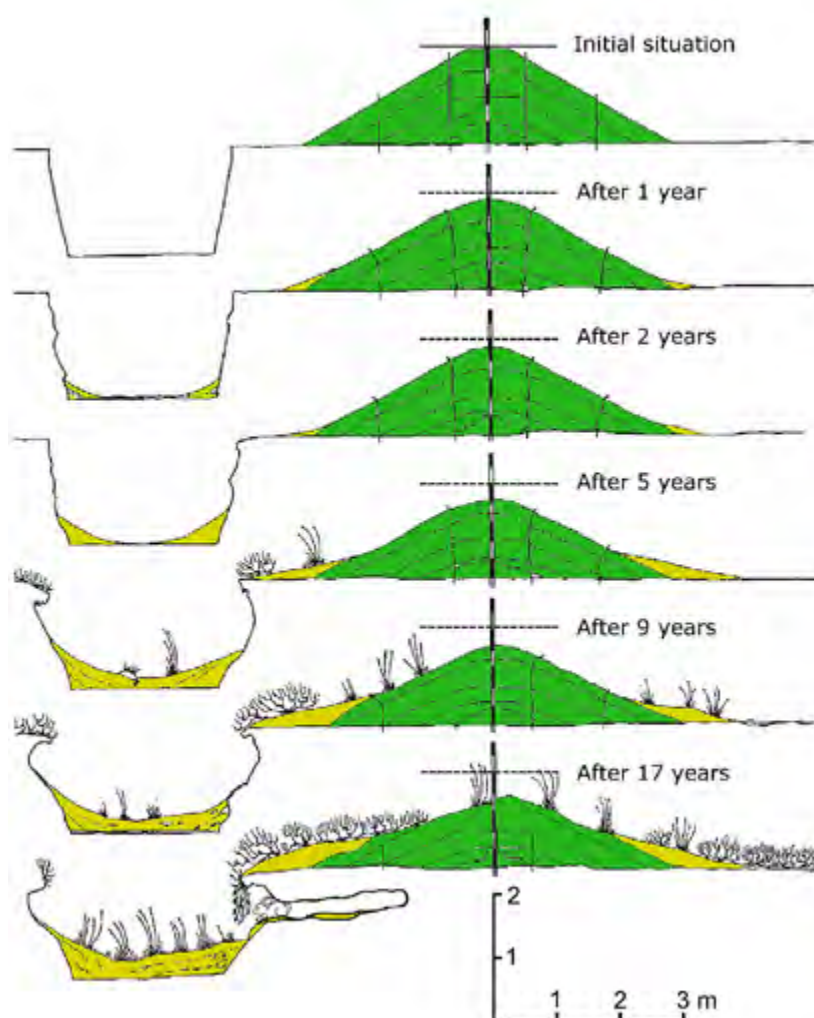


Fig. 4.3 Degradation of an experimental bank by erosion (after Rimmington 2004).

slopes and road banks are equally sensitive to run-off erosion (Fig. 4.3).

Soils with a high content of fine sand and silt but little organic material are particularly sensitive to slope erosion; loess is a case in point.⁸⁸ Fine-grained sandy soils with a very loose consistency (e.g. fallow fields on sandy soils) are especially susceptible to wind erosion.⁸⁹ Gillijns *et al.*, among others, discussed the impact of wind erosion on fields in the Antwerpse Kempen and Limburgse Kempen.⁹⁰ Wind erosion is also an issue on the Meeuwenduinen archaeological national monument near Burgh-Haamstede (Westeren Ban van Schouwen, National Monument 46.170).⁹¹ By the second half of the 20th century natural wind erosion on arable land had

⁸¹ Schiffer 1996; Sullivan & Dibble 2014.

⁸² Huisman 2009; Historic England 2016.

⁸³ Wood & Johnson 1978; Schiffer 1996; Canti 2003; Van Waijen 2001b; Huisman 2007.

⁸⁴ Langohr 1990; Louwagie, Noens & Devos 2005; Kwaad, de Roo & Jetten 2006. See also ALBON 2015.

⁸⁵ Seynaeve 1999; Reuler *et al.* 2014; Lascaris 2019, Section 2.2.5.

⁸⁶ Gillijns *et al.* 2005.

⁸⁷ Langohr 1990, 211; Poesen 1993; Kwaad, Van der Zijp & Van Dijk 1998; Kwaad, de Roo & Jetten 2006; Cerdà, Imeson & Poesen 2007; Winterraeken & Spaan 2010; Kinnell 2013; ALBON 2015.

⁸⁸ Oxford Archaeology 2002. The water-repellent nature of (moderately) humic sandy soils also contributes to water erosion (Ampe 1999).

⁸⁹ Lancaster 2009; Langohr 1990.

⁹⁰ Gillijns *et al.* 2005.

⁹¹ Kasbergen 2016; Provincie Zeeland 2017.

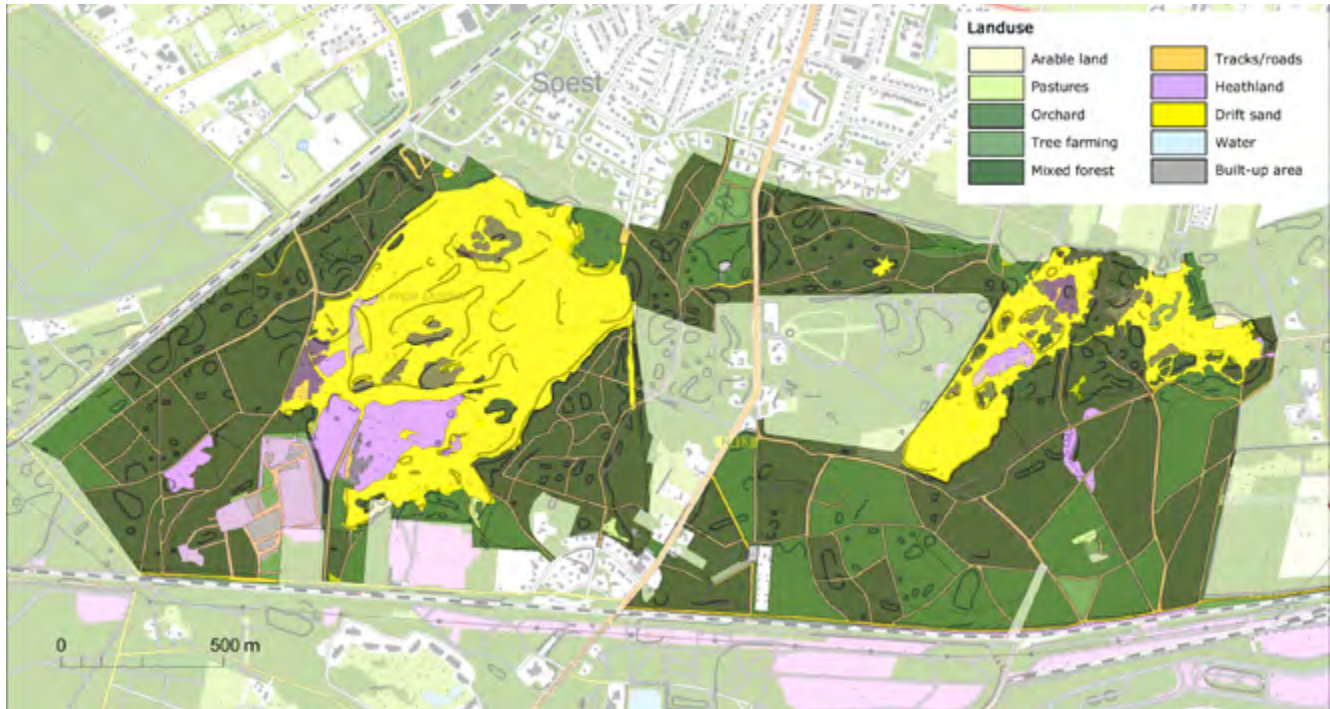


Fig. 4.2 Archaeological national monument De Lange Duinen, Soest (National Monument 45.995).

almost ceased, but today the process is deliberately stimulated again by removing the vegetation and other measures such as removing the turf and/or topsoil (see also Fig. 5.25).⁹²

Erosion on an exposed or overgrown archaeological site will ultimately lead to the loss of archaeological remains and features.⁹³ As soil material disappears archaeological features are either destroyed at once or gradually (or rapidly) ploughed away. If the erosion continues a site may ultimately be lost completely as its archaeological levels are constantly being truncated. In the Netherlands about 10% of the known archaeological sites are situated in areas with a moderate to severe risk of slope erosion.⁹⁴ Most of these sites have already sustained erosion-related damage, and some have almost completely disappeared.⁹⁵ A few sites on the other hand benefit from slope erosion; these are situated in locations where eroded soil material is redeposited, burying the archaeological remains below the colluvium.

The negative impact of soil erosion on heritage sites was illustrated by the publication in 2009 of the report *Erfgoedbalans* which presented the results of a study of the condition of Roman villa sites in the province of Zuid-Limburg.⁹⁶ Of the sixteen scheduled villa sites all but two were deteriorating as a result of ploughing and erosion. At six villa sites wall foundations had been partly destroyed while they were completely gone at two others. The two non-affected sites were both in locations where they were covered by eroded material (colluvium) from elsewhere.

4.2.2 Soil collapse and slide

On steep slopes or on the edge of escarpments, waterlogged soils on top of poorly permeable subsoils can start to slide. A landslide is a sudden, incidental instance of this type of erosion; if the process is slow and gradual the term is solifluction.⁹⁷

⁹² See e.g. Van der Valk *et al.* 2013.

⁹³ See e.g. Wilkinson, Tyler & Grieve 2006; De Groot 2006; Heeres 2014; Huisman & De Kort 2017; Huisman & Van der Heiden 2017.

⁹⁴ Beukers 2009.

⁹⁵ *Ibid.*, 272.

⁹⁶ De Groot 2006.

⁹⁷ Carson & Kirkby 1972; Heeres 2014.

Landslides and solifluction occur when the gravitational force acting on a slope exceeds the slope material's strength and cohesion and the amount of internal friction. The process may be initiated by pressure from e.g. heavy equipment, or when a sloping subsoil becomes waterlogged. Impermeable layers, such as a compacted subsoil, provide a sliding surface along which the topsoil can move downward. Occasionally landslides are triggered by soil vibrations from (heavy) traffic, freight trains, or pile frames (piles, sheet framing).⁹⁸ Escarpments can also collapse or slide if heavy agricultural machinery, construction equipment or lorries come too close to the edge.

Landslides and solifluction occur in uneven terrain (in the Netherlands found especially in the province of Zuid-Limburg) or along the edge of a pushed moraine (Wageningen, Ubbergen), or on any other steep slope (dikes, mottes, or the escarpments and old quarry faces of terps).⁹⁹ They can cause considerable damage to archaeological sites; after a collapse any association between soil features and site stratigraphy in different parts of the site may have become impossible to establish.

Instances of damage to archaeological national monuments due to landslides or solifluction have been recorded, for example during restoration activities on earthen banks and canals (e.g. Gennepershuis), or when old soil profiles were being studied. Examples of escarpment erosion have been reported from the terp regions in the northern Netherlands (Fig. 4.4).

4.2.3 Soil disturbance by wild animals or cattle

Wild boar and pigs rooting in the ground can seriously disturb soil features and layers, and they can also damage tree roots which in turn increases the risk of windfall. Especially wild boar root extensively and to a depth of several decimetres. The animals are attracted by low vegetation with plenty of soil insects, and by clearances such as those surrounding well-managed burial mounds. Wild boar even overturn heavy boulders up to 100kg.



Fig. 4.4 Collapsing escarpment along the north face of the Oostrum terp (National Monument 45.391). The cause is uncertain; perhaps rotting tree roots of a few cut-down trees or flowing water in the surrounding ditch was undermining the slope (photo: Van Doesburg & Stöver 2018).

Cattle and horses grazing on wet or damp soils may cause local trampling (Fig. 6.19) or leave deep ruts on visible archaeological national monuments such as terps and burial mounds.¹⁰⁰ Gaps in the vegetation cover negatively affect the soil water content and as such contribute significantly to soil erosion (Section 4.2.1).¹⁰¹ Furthermore, horses, bulls and the red deer stags (when they are in rut) will create holes. Cattle will also compact the soil, thus reducing water infiltration and increasing

⁹⁸ www.kivi.nl/afdelingen/geotechniek/geonet/dossiers/trillingen; see also Meijers 2007.

⁹⁹ See also Arjaans 1990.

¹⁰⁰ E.g. Van Doesburg, Van der Heiden & Stöver 2019. De Moor, Kars & De Groot 2018, 715. See also Van der Heiden & Feiken 2018.

¹⁰¹ Oostindie et al. 2003.



Fig. 4.5 Flock of sheep, Ballooërveld (photo: Jos Stöver/erfgoedfoto.nl).

the risk of surface run-off and erosion (on slopes).¹⁰² To a lesser degree this also applies to small livestock like goat and sheep; sheep are less harmful because they have less impact on the vegetation and the soil than other livestock (Fig. 4.5).¹⁰³

Additional damage by wild animals and livestock to archaeological subsurface remains tends to be limited. However, damage to visible archaeological national monuments and archaeological levels close to the surface can be more severe. Several field inspections at national monument Wervershoof-Eendenkooi (Medemblik Municipality) recorded trampling on the burial mounds and slope damage caused by cattle.¹⁰⁴ A group of wild boar can churn up a large area to a considerable depth in only one night.

¹⁰² Trimble & Mendel 1995; Dillon 2007; Huisman & Ngan-Tillard 2019.

¹⁰³ Baas & Raap 2010.

¹⁰⁴ Van der Heiden & Feiken 2018; National Monument 46.173.

4.2.4 Rampant growth of trees, shrubs, and helophytes

The relationship between tree roots and damage to constructions and archaeological remains has been the subject of extensive study.¹⁰⁵ Overall some tree species develop more and thicker roots than others, and thicker roots cause more damage than thinner ones. Tree roots are opportunistic and will grow in the direction of least resistance. If growth conditions in the deeper soil layers are unfavourable most of the root mass will be concentrated higher up, which increases the risk of root damage. A high water table will likewise stimulate trees to produce shallow root systems, and other growth conditions have an effect on tree root depth as well.¹⁰⁶ Many roots have a natural tendency to grow horizontally.

Exotic species of shrubs may also pose a threat to archaeological national monuments. The extensive root system of Japanese knotweed (*Reynoutria japonica*), which can reach a depth of two metres, is a source of widespread bioturbation. Slopes may become unstable (desiccation, root penetration), pavements and foundations may be damaged, and deeper subsurface features and find-bearing layers can also be affected. Likewise, the rhizomes of common reed can damage subsurface remains in canal bottoms and shores or in marshy terrain where archaeological remains lie just below the surface. For a further discussion see Section 4.4.4: Plant roots and root impact.

A secondary effect of rampant plant growth is that certain vegetation types will attract rabbits, foxes, mice and rats, who gladly avail themselves of the opportunity to dig and burrow in safety; and livestock are also drawn by the shade shrubbery provides.



Fig. 4.6 Fallen tree; Twello (photo: Jaco van Hal 2018).

4.2.5 Tree fall

Trees can have a negative impact on archaeological remains not only by their root action. When a tree is blown over by the wind, root ball, soil and all, the damage to archaeological remains can also be extensive^{107, 108} (Fig. 4.6). Fallen trees can disturb the soil down to a depth of 120 to 150cm or more,¹⁰⁹ and leave 5 to 7m-long pits. However, the deeper a root system penetrates into the soil the less compact it becomes and the thinner the individual roots, so that the impact of windfall on archaeological remains at a greater depth will be correspondingly less.

On wet soils the risk of windfall is greater for tree species that are intolerant of high groundwater. Conifers tend to be more vulnerable than deciduous species because the latter lose their leaves in winter, which is usually the stormy season. Other factors also play a role. Coppices tend to be less prone to windfall. In larger woodlands many trees will be affected by snowfall, drought, lightning strikes and forest fires, and in areas with dense tree cover the risk that such trees will succumb to windfall and set off a chain reaction is increased.¹¹⁰ Forest rejuvenation is another risk factor, because during storms the wind force can penetrate deep into clearances and trees on the edges of a recent clearance have not yet adapted their root systems to this greater wind exposure.

¹⁰⁵ Biddle 1998; Cox et al. 2001.

¹⁰⁶ Coutts 1989; Canadell et al. 1996.

¹⁰⁷ Langohr 1993.

¹⁰⁸ Crombé 1993; Kooi 1974; Wood & Johnson 1978; Boosten & Penninkhof 2019, 75.

¹⁰⁹ Langohr 1993.

¹¹⁰ Kooi 1974; Wagner 1992.



Fig. 4.7 Archaeological national monument Hunenborg, Volthe, province of Overijssel (National Monument 46.005), a probably 11th/12th-century ringfort. Around 1660 Dutch antiquarian Johan Picardt (1600-1670) described the remains of this ringfort as 'completely overgrown and destroyed'. Especially the many windfalls had a disastrous effect on the archaeological remains. The inner bailey, which over the years had become completely overgrown by trees and shrubbery due to a lack of maintenance, has now been cleared.

Windfall is a significant risk factor where leaning or less healthy trees grow on or near smaller visible or shallow archaeological sites.¹¹¹ The actual amount of windfall-related damage depends on the characteristics of the monument and the extent and degree of the disturbance (Fig. 4.7). Often the damage is limited, but even then there may be secondary effects. The created clearances, large or small, not only allow more light to reach the surface but also lead to changes in soil humidity, and both factors stimulate the growth of shrubs and ground vegetation as well as bioturbation.¹¹² Shrubs and clearances attract herbivores and burrowing animals like rabbits and wild boar, and this in turn leads to more soil disturbance.¹¹³

4.2.6 Moss and lichen

Another specific form of damage occurs when moss, lichen and algae grow on archaeological materials on the surface, such as stone or brickwork (Fig. 4.8).¹¹⁴ An overgrown surface will remain damp and may start to flake and fragment under the influence of frost or the combination of expansion and shrinkage. Lichen also secretes acids which dissolve a thin layer of the stone, but the damage usually goes no further since the lichen cover also protects the surface. On the whole, moss or lichen tend to cover a limited area and the risk of damage to national monuments is negligible,¹¹⁵ while the scientific value of the frequently rare species and other wall vegetation, as for instance *Asplenium ceterach* (Rustyback) or *Asplenium adiantum-nigrum* (Black spleenwort), is considerable.¹¹⁶

¹¹¹ Boosten & Penninkhof 2019; Datema 2015.

¹¹² Langohr 1993.

¹¹³ As occasionally on burial mounds that are kept free from trees; Fred Brounen, Cultural Heritage Agency of the Netherlands, oral communication.

¹¹⁴ Altieri & Ricci 1997; Warscheid & Braams 2000; Nuhoglu *et al.* 2006. See also Colpa & Van Zanden 2006 on moss growth on megaliths.

¹¹⁵ Rijksdienst voor Archeologie, Cultuurlandschap en Monumenten 2008, 5.

¹¹⁶ Colpa & Van Zanden 2006.



Fig. 4.8 Moss-covered pavement pole re-used as a grave marker; Stryper cemetery, Midsland (National Monument 46.015, photo: Jos Stöver/erfgoedfoto.nl).

4.3 Soil processes

Important natural soil processes which affect archaeological remains in the top few decimetres below the surface are physical weathering (frost-thaw cycles, expansion/shrinkage by saturation and desiccation), decomposition by aerobic soil organisms, and bioturbation (animals, plants). The effects of these processes are weathering, mineralization, fragmentation/shattering, and displacement/transportation of objects and materials in the ground. These phenomena are very widespread and they can accelerate when archaeological remains have become more exposed to air in the surrounding soil as a result of (agricultural) tillage, soil desiccation, plant action or erosion.¹¹⁷ Bioturbation also occurs below the surface; this is discussed in a separate section (4.4).

4.3.1 Physical weathering

Obviously, fracture and extensive fragmentation are the primary risk factors affecting pottery, stone, glass, and bone.¹¹⁸ Archaeologists are familiar with this form of mechanical decay, for complete objects are

rarely found; usually a few fragments or mere crumbs are all that is left.

In the upper soil strata the influence of atmospheric processes on the soil often leads to fracture and fragmentation (pedologists use the term physical weathering). Especially important in this context are frost/thaw and expansion/shrinkage cycles and their impact on soil aggregates and porous materials.¹¹⁹ After repeated winter freezing and thawing damp pottery will fracture and disintegrate into dust.¹²⁰ Many materials, such as pottery and natural stone, are hygroscopic: they absorb moisture to match the humidity of their environment. This renders such materials particularly vulnerable to frost damage.

Episodes of (severe) frost and thaw alternating at regular intervals also affect dense materials like stone, including flint, to a soil depth of several decimetres. Subsurface artefacts in soils that retain moisture (e.g. clay or loess, together representing c. 25% of the soils in the Netherlands) are more vulnerable to frost damage than artefacts in drier sandy soils.

Non-silty clays and (silty) loess shrink when dry, reducing the total volume of pores and increasing the density. Under dry conditions clay soils can become extremely hard and even crack

¹¹⁷ Greathouse *et al.* 1954.

¹¹⁸ According to Kars & Smit 2003 and Huisman 2009, respectively. See also Hunt 2017.

¹¹⁹ Breeuwsma & Drijver-de Haas, Ch. 6, in: Locher & De Bakker 1990.

¹²⁰ Swain 1988. Farmers on clay soils make use of this process by ploughing their fields in autumn to allow the frost to break up the clods.



Fig. 4.9 Mud cracks in humic non-silty clay (photo author, river Berkel, Lochem).

(Fig. 4.9). Under wet conditions, when the soil expands, these cracks will (mostly) close again.¹²¹ In porous or hygroscopic soils, repeated wet and dry cycles are thus accompanied by matching cycles of expansion and shrinkage. Under such conditions artefacts can start to flake, fracture, or be completely pulverized.

In itself fragmentation is not particularly harmful to sites as long as the archaeological materials remain recognizable; pulverization in particular will diminish their information value. However, the quality of a national monument will be lost as fragmented archaeological artefacts are increasingly scattered due to the displacement of their soil matrix.¹²²

4.3.2 Mineralization and decomposition by soil organisms

Soil animals and soil microflora play an important role in the conversion of organic material into humus and inorganic minerals. This form of decomposition is the outcome of three different processes:¹²³

1. At the bottom of the chain are the soil-dwelling animals, mainly insects and worms (see also Section 4.4), who cut up and eat

plant remains to sustain their own metabolism, converting them into (mainly) CO₂ and nutrients. These soil animals mix decayed organic material into the soil (bioturbation; see Section 4.4). The faeces of some animal species – whether or not combined with mineral soil particles – in turn feed other yet smaller animals or provide nutrients for microbial colonization by fungi and aerobic bacteria.

2. Chemical weathering of non-carbonized organic material is largely the result of the actions of worms, bacteria, or fungi.
3. Chemically altered materials that become soluble in water react with mineral soil particles or are washed down into deeper soil strata and/or the groundwater.

During this process, called mineralization, organic matter disintegrates and decomposes into ever smaller components.¹²⁴ Not only ecological materials such as macro-botanical remains and pollen are affected but also other vegetable matter as well as animal remains.¹²⁵ This occurs mostly under oxygenated conditions. Some species of bacteria are able to convert organic matter (e.g. leather) in anaerobic environments, but this is usually a slow process.¹²⁶ Bacteria and fungi also absorb oxygen as part of their digestive process; in wet and poorly permeable soils (peat, clay) but also inside waterlogged organic remains (wood, bone) this process may cause oxygen depletion and so produce reducing conditions (Section 5.4.7).¹²⁷

¹²¹ Locher & De Bakker 1990; Schiffer 1996, 141 ff.

¹²² Trow & Holyoak 2008; Trow 2010; Behm et al. 2011; Dain-Owens et al. 2013.

¹²³ Chapin et al. 2002, 151 ff.

¹²⁴ Locher & De Bakker 1990; Sunner 2000; Chapin, Matson & Mooney 2002; Hopkins 2004.

¹²⁵ Havinga 1984; Van Waijen 2001b; Huisman 2009.

¹²⁶ Hopkins 2004.

¹²⁷ Huisman 2009, 168.

Humification and mineralization by mesofauna, fungi and bacteria are fairly rapid processes.¹²⁸ A long-term monitoring study of the condition of archaeological sites in Limmen (province of Noord-Holland) showed that within six years after the groundwater table had been lowered virtually all fossil pollen had been seriously compromised.¹²⁹ During the same period the number of microscopic animal borrows and cavities, visible in thin-section, had increased by 30%.¹³⁰ Furthermore, within ten years of the intervention all archaeologically significant non-carbonized organic material, and with it much of the information value of the archaeological sites in the area, was lost. Because organic material can also be a significant factor in creating colour contrast between soil features and the surrounding soil, such features can quickly fade due to microbial activity.

4.4 Bioturbation

4.4.1 Definition

The term bioturbation applies to processes in which the soil and the archaeological remains it contains are churned, penetrated and mixed by animal activities.¹³¹ Bioturbation is a widespread natural process that occurs in virtually all soil types containing organic nutrients, including arable land, grassland, nature areas and urban soils. As such it is an important baseline component in the degradation of archaeological heritage.¹³²

Table 4.1 Soil-dwelling animal species in the Netherlands (data source: Berg 2016).

Group	Number of soil dwelling or surface dwelling species
Worms	31
Snails	116
Amphibians	0
Reptiles	8
Mammals	31
Insects	4.947
Arachnids	652
Chilopods	113
Crustacea	44
Hexapoda	343
Total	6.304

The prime factor responsible for bioturbation are the activities of larger and smaller invertebrates such as worms, but the role of insects and arthropods is also significant (Table 4.1, Section 4.4.3). Soils may contain huge numbers of especially tiny insects such as springtails, mites, beetles, or ants.¹³³ The degree to which these animals will disturb the soil largely depends on soil oxygen content and the amount of fresh organic matter. Other potential sources of bioturbation are vertebrate species which live (partly) below the surface, tunnelling or burrowing through the soil (Section 4.4.5). Underground holes and dens (badgers, foxes) and tunnels (moles, rabbits, mice, rats, badgers, foxes) leave behind 'natural' soil features.¹³⁴ Only larger animal tunnels are still easily recognizable by the naked eye in a soil profile (Fig. 4.10).¹³⁵

Plants, and especially plant roots, can also have a negative impact on archaeological remains (Section 4.4.4).¹³⁶ Roots will penetrate the soil layers, pushing aside soil particles and piercing or erasing archaeological layers and features. Root pressure can damage and vertically shift not only objects and occasionally constructions, but it can also distort or even mix archaeological cultural layers.¹³⁷ Moreover, plant roots influence the soil moisture content and soil formation processes (leaching, oxidation and reduction; see Section 4.4.4).

¹²⁸ Chapin, Matson & Mooney 2002; Molenaar, Exaltus & Van Waijjen 2003.

¹²⁹ Van Waijjen 2001b, 28.

¹³⁰ Molenaar, Exaltus & Van Waijjen 2003; French 2003.

¹³¹ Wood & Johnson 1978; Schiffer 1996, 207.

¹³² Chapin, Matson & Mooney 2002; Wilkinson *et al.* 2009.

¹³³ Nearly 22% of all animal species in the Netherlands are surface/soil dwellers (Berg 2016; see also Weeda, Ozinga & Jagers op Akkerhuis 2006).

¹³⁴ Dunwell & Trout 1999; Rimmington 2004, 60.

¹³⁵ Brussaard & Runia 1984.

¹³⁶ Wood & Johnson 1978; Schiffer 1996.

¹³⁷ Johnson 1998; Cox *et al.* 2001; Crow & Moffat 2004, 2005.

4.4.2 Bioturbation-related damage

Bioturbation of archaeological remains by animals or plants is a slow process that will mostly have run its course long before a site is discovered and scheduled. Many an archaeological trench in the Netherlands shows the telltale signs of centuries of plant root action and animal burrowing, but nonetheless still contains at least some legible features and artefact scatters. The extent of animal and vegetation-related damage to archaeological remains appears to be limited and is usually invisible. Nonetheless higher soil levels, where nutrients and oxygen are concentrated, can be completely homogenized and features may have merged with the surrounding soil to the extent that they are no longer visible.¹³⁸ A good example of deeply disturbed and homogenized soils in which features and stratigraphy have mostly faded are the moder podzols on the Dutch moraines.

Bioturbation is not limited to the homogenized (top) layers. In exceptional cases root systems and animal burrows can reach several metres below the surface. Bioturbation is particularly harmful to archaeological sites if the process is rapid. Examples are the disintegration of archaeological levels with non-carbonized organic remains when soil conditions become aerobic; extensive animal burrowing on smaller national monuments such as burial mounds and megaliths; or animals undermining steep slopes or rooting through the vertical profiles of visible archaeological landscape elements.¹³⁹

4.4.3 Mesofauna

After fungi and bacteria, earthworms are probably the chief organisms involved in the displacement, mixing and processing of soil particles and the disintegration of archaeological remains.¹⁴⁰ The number of earthworms in the soil mostly depends on soil conditions; the highest worm concentrations occur in weakly alkaline or neutral soils¹⁴¹ while the animals tend to avoid acidic soils (e.g. peat). A second important factor is soil water content. Earthworms cannot live in

a waterlogged environment and especially in the absence of oxygen.¹⁴² Under normal conditions earthworm activity clusters at 15 to 30 cm -GL, corresponding to the aerobic, non-compacted top levels that contain (organic) nutrients.¹⁴³ Of the deep-living (anecic) species, unploughed fields can contain up to 150 burrows per square metre at a depth of 1 m or more, depending on soil conditions and soil density.¹⁴⁴

Most worm species, however, live near the surface in the upper soil layers (which are often already disturbed). The dominant species among this group of topsoil/subsoil dwellers (endogeic species; Fig. 4.11) make temporary and usually horizontal burrows just below the surface (0-30 cm).¹⁴⁵ The burrows of anecic species, who prefer deeper levels, can be found up to 120 cm below the surface; these species are rare, however (Table 4.2). Worm tunnels provide ideal corridors for plant roots.¹⁴⁶

Archaeological remains seem to be little affected by worm activity (Fig. 4.11). The most disruptive impact of worm activity is burrowing or tunnelling. Worm tunnels are usually 1 to 10 mm in diameter and may dislocate artefacts and undermine larger objects. In his 1881 publication on earthworms, Charles Darwin already described how a boulder on his lawn was gradually pulled into the ground by earthworms,¹⁴⁷ and he also studied earthworm activity near Stonehenge. Another important effect of worm activity is that worms create soil conditions which enable fungi to survive at greater depths. This may increase the mineralization of sensitive organic materials.¹⁴⁸ A case in point is the Late Neolithic site at Simonshaven-Polder (Voorne-Putten), where the archaeological remains had been disturbed by increased worm activity during a particularly dry summer.¹⁴⁹

Insects and (especially) their larvae also live in soil layers where food is plentiful. This group of temporary soil dwellers includes many fly and beetle species. Scarab beetles, which live in sandy and loamy soils, dig tunnels measuring up to 14 mm across and up to 20 cm long,¹⁵⁰ down to a depth of 2 m or at least until the capillary zone.¹⁵¹ Ant species are common in extensively grazed grasslands and in forest areas.¹⁵² Despite their small size ants can cause fairly extensive

¹³⁸ Schuylenborgh, Slager & Jongmans 1970.

¹³⁹ See e.g. Boosten & Penninkhof 2019, 76.

¹⁴⁰ Wood & Johnson 1978; Stein 1983; Lee 1985; Armour-Chelu & Andrews 1994; Gobat *et al.* 1998; Canti 2003; Valckx *et al.* 2009; Blouin *et al.* 2013; Pfiffner 2017.

¹⁴¹ *Ibid.*; see also Lee 1985.

¹⁴² Bubel 2003; Lee 1985.

¹⁴³ Atkinson 1957; Lee 1985; Valckx *et al.*

2009, 11 and 23; Pfiffner 2017.

¹⁴⁴ Pfiffner 2017.

¹⁴⁵ Valckx *et al.* 2009, 23.

¹⁴⁶ Barton 1992; Pfiffner 2017.

¹⁴⁷ Darwin 1881: The formation of vegetable moulds, through the action of worms, with observations on their habits, London, John Murray.

¹⁴⁸ Havinga 1984; Canti 2003.

¹⁴⁹ Van Heeringen & Theunissen 2002.

¹⁵⁰ Brussaard & Runia 1984; Brussaard 1985.

¹⁵¹ *Ibid.*; Brussaard & Slager 1986.

¹⁵² Langohr & Crombé 1999.

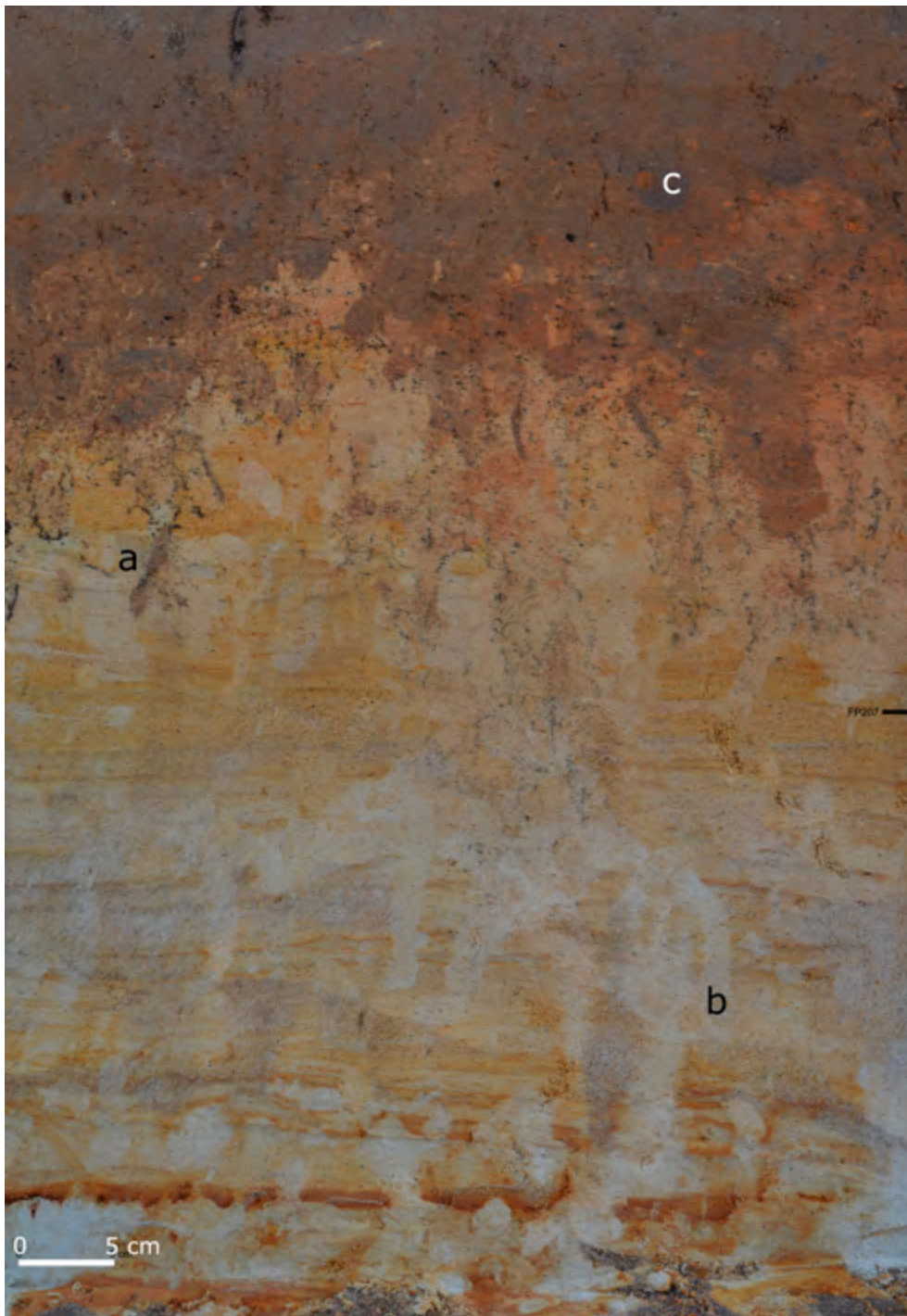


Fig. 4.10 Bioturbation due to plant root action (a), burrowing by beetles (b), and the activities of a small mammal (c) in a mineral humic layer (above a coversand profile), Borne-Oude Aalderinkskamp (photo author).

disturbance and sometimes even damage. Their irregular nests easily collapse, which not only disrupts the soil stratigraphy but may also lead to subsidence.¹⁵³ The potential impact of insect activity on the information value of

archaeological national monuments is unknown but it appears to be minimal. Ant colonies are often perceived as 'problematic', particularly when collapsing corridors led to the collapse or subsidence of pavements or objects.

¹⁵³ Wood & Johnson 1978; Langohr & Crombé 1999; Bubel 2003. Other insect species besides ants and beetles which also dig subsurface corridors include wolf spiders, mole crickets (*Gryllotalpa gryllotalpa*) and tiger beetles. Certain wasps, bees and bumblebees also make tunnels (Brussaard & Runia 1984).

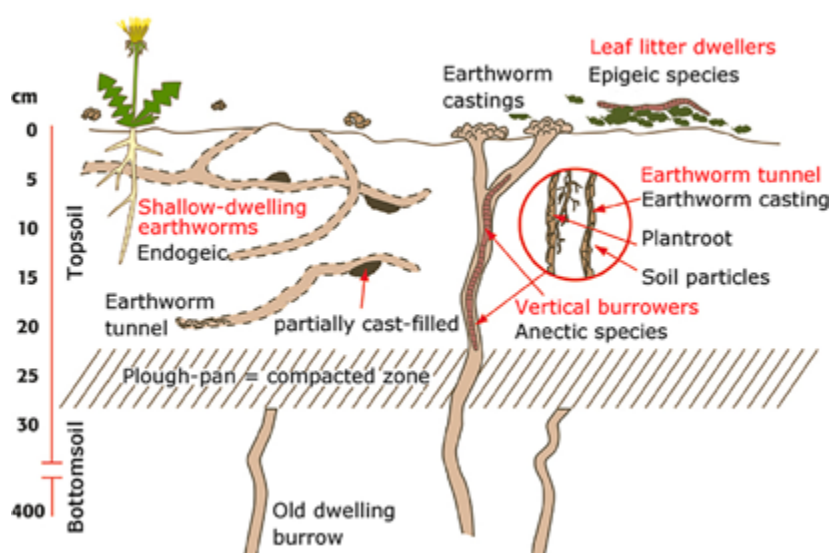


Fig. 4.11 The three most common earthworm species each have their own specific habitat and feeding habits (image: Pfinner 2017/Bioforum Vlaanderen vzw).

4.4.4 Roots and root impact

The roots of trees and shrubs can disturb archaeological remains by dislocating, pulverizing or piercing them,¹⁵⁴ as a result of which archaeological cultural layers may be distorted or even mixed.¹⁵⁵ A number of factors influence plant root depth (root penetration), including the structure of the topsoil and subsoil, soil aeration and the groundwater situation, the presence or absence of impermeable or compacted layers in the soil profile, temperature, humus content, acidity, nutrient content, and competition with other plants.¹⁵⁶

Overall, trees put down deeper roots than shrubs.¹⁵⁷ All tree roots need oxygen to breathe but some species have developed ways to cope with situations when oxygen is scarce. On soils with a permanently high groundwater table trees tend to develop shallow root systems that cover a large area. Tree roots will also stay at a more shallow depth if sufficient precipitation remains in the upper soil layers. Roots can also

Table 4.2 Bioturbation by animals (after Louwagie, Noens & Devos 2005).

Type dier	Favourite habitat	Soil preferences	Depth	Burrow/tunnel diameter	Burrow/tunnel length
			cm	cm	m
Cattle and pigs	Grassland	-	-	-	-
Rabbits	Grassland and woodland edges	Well-drained, preferably sandy soils	75-450	10-15	5-250
Badgers	Grassland and open woodland	Well-drained sandy to loamy soils	100-400	25-60	20-100
Foxes	Woodland/meadow/park/dunes/heath	Well-drained, preferably sandy soils	-	-	-
Hamster	Arable fields and semi-open landscapes.	Well-drained loamy soils	30-200	7	-
Rats	Rabbits holes, dung heaps, hedges, storage areas	-	<=50	6-9	-
Field mice	Grassland	Damper soils	<=70	<=16	-
Moles	Mainly grassland, open woodland	Sandy soils	25-275	6	-
Earthworms	Meadows	Not too dry, neutral to slightly alkaline soils	<=120	0,1-1	-
Scarab beetle	-	Sandy and sandy/loamy soils	<=200	1,4	0,2
Ants	Meadows and woodland	-	20-30 up to 100	-	-

¹⁵⁴ Wood & Johnson 1978; Schiffer 1996.

¹⁵⁵ Johnson 1998; Cox *et al.* 2001; Crow & Moffat 2004, 2005.

¹⁵⁶ Stone & Kalisz 1991; Canadell *et al.* 1996; Crow 2005.

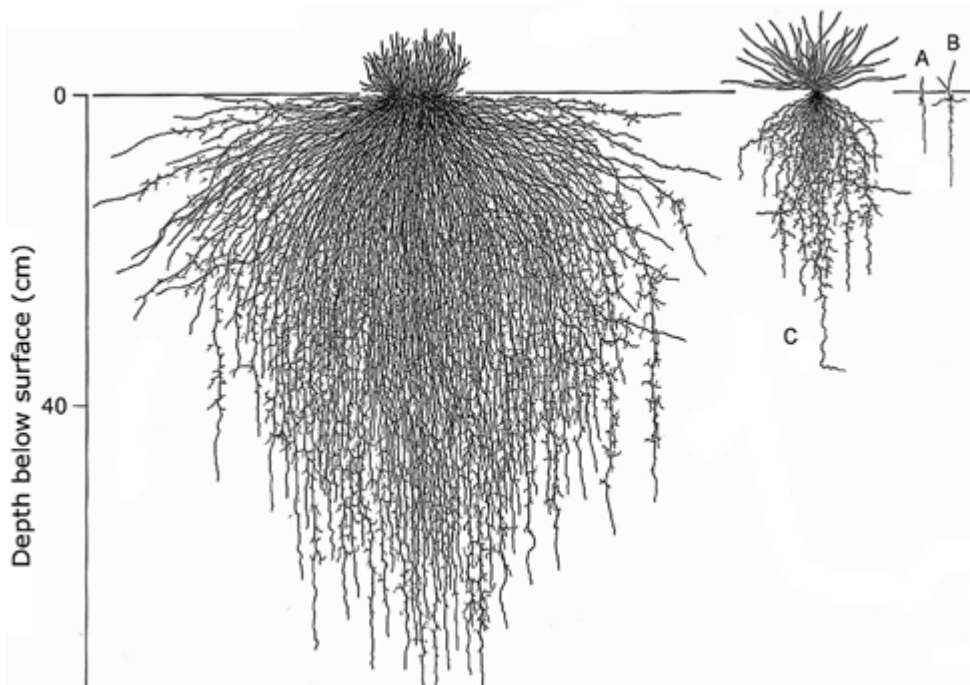


Fig. 4.12 Root system of English ryegrass at different stages of growth. A: 2 weeks after sowing; B: 4 weeks after sowing; C: 10 weeks after sowing; D: 14 months after sowing (after Kutschera & Lichtenegger 1982).

reach deeper groundwater provided they are able to penetrate the soil at those depths and there is enough oxygen. Roots will seek for groundwater up to two metres below the surface but usually not beyond, as both the temperature and oxygen levels become too low. However, under favourable conditions roots can go very deep. In other words, root depth is independent of the tree species.¹⁵⁸

Agricultural crops have root systems of varying depth, depending primarily on the age of the plant and on soil conditions. Annual legumes (peas, beans, vetch) produce roots with a length of 55 to over 85cm while the roots of other annual crops (oats, maize, potatoes) reach 55cm or more; especially oats and maize can penetrate 85cm below the surface or even deeper.¹⁵⁹ Some perennial crops such as ryegrass (*Lolium sp.*) and clover can reach a depth of several decimetres (Fig. 4.12), and the idea that grass root systems are always shallow needs some modification.¹⁶⁰ Nonetheless, in most ryegrass species 99% of the root system will be concentrated in the top 35-40cm.

The root systems of many plant species determine where soil organisms will cluster and

therefore where bioturbation will occur.

Furthermore, some plant roots seem to seek out soil features. The slightly higher concentrations of organic material in archaeological features are a source of nutrients, and the somewhat looser soil structure provides less resistance. The increased moisture intake of plant roots can dry out the surrounding soil matrix, causing materials to disintegrate and soil features to fade and become illegible. Excavation profiles often reveal the impact of root systems on local oxidation and reduction processes (iron and rust stains, bleaching) around root clusters, as well as disturbances of the (micro)stratigraphy (Fig. 4.10).¹⁶¹ The volume of water evaporation by trees is approximately twice that of grass so that the presence of trees will greatly reduce the soil moisture content as far down as their roots can reach (which depends on local soil conditions). During a prolonged drought escarpments may develop deep, long cracks, particularly in dikes on peat and clay soils.

Archaeological layers below groundwater level will be little affected by tree roots, since trees cannot survive when their root systems are permanently under water. The root systems of most species will therefore stay above

¹⁵⁷ Ruark, Mader & Tatter 1982.

¹⁵⁸ In ideal soil and moisture conditions, tree roots can reach a depth of over 10m.

¹⁵⁹ Ten Cate *et al.* 1995; Van Lieshout 1956, 10 ff., Fig. 16. See also Kutschera, Lichtenegger & Sobotik 2009. Maximum root depth for maize in the Netherlands is c. 100 to 150cm, but if limiting factors are present the actual depth can be much less than that.

¹⁶⁰ Van Lieshout 1956; Deru, Van Eekeren & de Boer 2010.

¹⁶¹ Limbrey 1975; Wood & Johnson 1978.



Fig. 4.13 Megalith D03 near Midlaren, surrounded by oak trees (National Monument 532.467).

groundwater level, with the exception of water-tolerant species such as willow, alder and bald cypress (*Taxodium distichum*). The rhizomes of reed on the other hand can perforate anything below the waterline.¹⁶² Some reed species can be invasive and tend to displace other plants.¹⁶³

Reed grows in different forms depending on whether a location remains dry during most of the year, floods only occasionally, or is more or less permanently inundated. Each set of conditions will produce different root systems. On dry soils, reed will produce deep roots to search for groundwater; in wet conditions the roots will form a dense mat of thick rhizomes. At the UNESCO World Heritage Site of Schokland reed root systems were observed to be much denser and more coarsely structured on wet soils than on the adjoining drier soils.¹⁶⁴ Furthermore, especially reed will release more oxygen into the soil as its roots go deeper.

Other plant species such as bracken (*Pteridium aquilinum*) also propagate by putting out thick black rhizomes. Bracken roots easily

branch out below the surface, sometimes producing an extensive network of criss-crossing rhizomes, a 'root mat', but the roots usually do not grow much deeper than c. 20 cm below the surface.¹⁶⁵

The possible extent of root damage to archaeological remains is not always obvious and usually invisible. In theory, root penetration, and specifically penetration of features and archaeological strata, disrupts the internal cohesion of the archaeological assemblage, thus reducing its physical quality.¹⁶⁶ However, archaeological levels at many sites in the Netherlands bear the traces of centuries of root action, but their features and artefact distributions are nonetheless still 'legible'. All in all, plants seem to be responsible for only a limited part of the damage to archaeological remains. What damage does occur is usually caused by the forcible removal of root systems. Although the roots of agricultural crops often extend below the plough soil, this too does not seem to have a significant impact on

¹⁶² Canadell *et al.* 1996; Tjelliden *et al.* 2016.

¹⁶³ Tjelliden *et al.* 2016.

¹⁶⁴ Hans Huisman, Cultural Heritage Agency of the Netherlands, oral communication.

¹⁶⁵ FLORON distribution atlas vascular plants (consulted January 2020).

¹⁶⁶ English Heritage 2004; Datema 2015.

archaeological information value. Finally, and perhaps obviously, the deeper below the surface the archaeological remains, the less vulnerable they are.

In specific cases root action can damage archaeological national monuments if the process for some reason speeds up. Examples of accelerated root action impact are the encroachment of deep-rooting invasive species on a national monument, windfall, or root pressure on constructions and layers.

4.4.5 Mammals and bioturbation

Although the question whether burrowing mammals should be considered 'bioturbation' is open for debate (and a matter of definition) their rooting and digging can undoubtedly mix and disrupt the soil. Field archaeologists are well acquainted with the effects of mole activity on the soil. This has even given rise to the 'field jargon' term 'mole layer' (*mollenlaag*), a disturbed layer which needs to be removed first before a proper archaeological surface can be prepared (Fig. 4.14). These small animals live in complex tunnel systems of up to 100m long or more which sometimes comprise hundreds of molehills.¹⁶⁷ The tunnels measure c. 6cm across and are situated between 25 ('plough soil') to 1.5m below the surface, the depth where the animals find their favourite food: earthworms.¹⁶⁸

Small rodents live in open areas, woodland, and built environments. Most species seem to be harmless with regard to archaeology. Field mice, voles and shrews, for instance, often live in shallow dens and dig corridors through the upper (often already disturbed) layers. Field mice tunnels usually run at depths of 5 to 30cm and their nests are situated c. 22cm deep.¹⁶⁹ Wood-mouse tunnels are deeper, up to 50cm below the surface, and some of them can be up to 6m long. In exceptional situations mice tunnels can be abundant; concentrations of up to 15 to 20 tunnels per m² have been recorded.

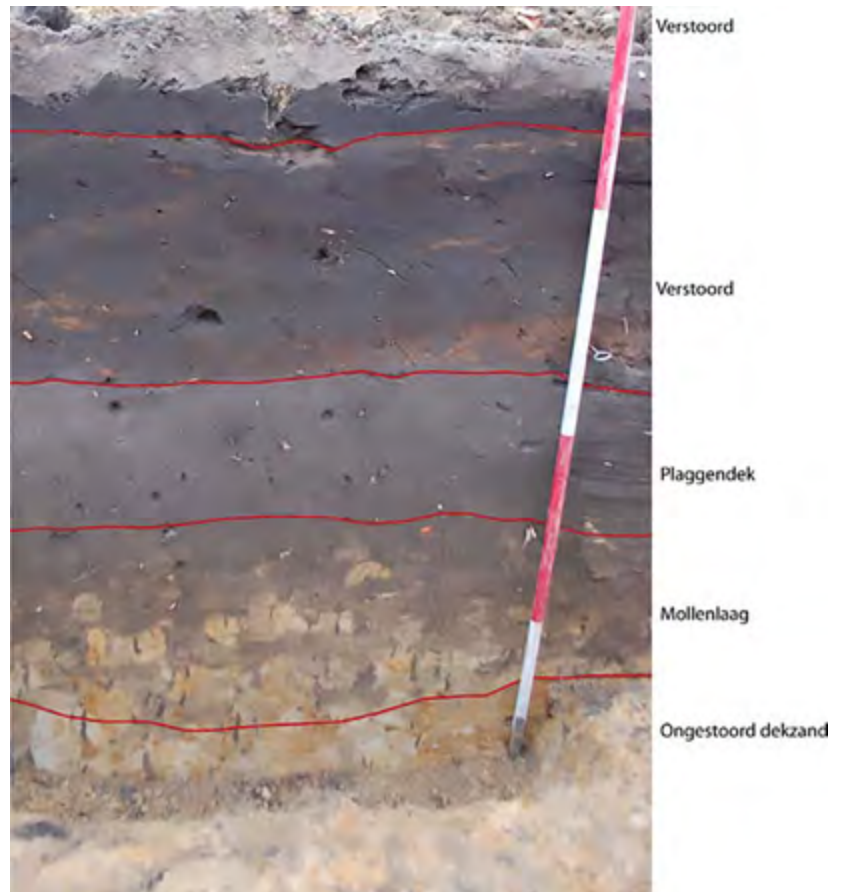


Fig. 4.14 Vertical profile, Ceintuurbaan, Deventer. A so-called 'mole layer' is clearly visible in the top section of a coversand substrate, below a disturbed sod layer (photo: Archeologie Deventer).

Rats prefer damp and fairly cool habitats. In the Netherlands, brown rats and muskrats can be found in reed vegetation and along watercourses. Brown rats make their nests in old rabbit warrens or river banks, or between stones or tree roots. Although not very good diggers, brown rats can make tunnels up to 50cm deep and 9cm across.¹⁷⁰ Particularly muskrats can do a great deal of damage. For their tunnels these animals prefer the banks of stagnant or flowing bodies of water with a dense aquatic and shore vegetation, but they will also dig through dikes. Because of this they are considered a pest, for dikes and (railway) embankments may subside as a result and agricultural vehicles can sink into the bank of a ditch. Muskrat activity is a problem in for instance the scheduled west section of the former commons of the historical town of Bunschoten (National Monument 45.276).

¹⁶⁷ Wood & Johnson 1978; Dunwell & Trout 1999.

¹⁶⁸ www.zoogdierveniging.nl. Sometimes moles dig deeper tunnels to escape a threat.

¹⁶⁹ www.zoogdierveniging.nl; Wymenga et al. 2015.

¹⁷⁰ Dunwell & Trout 1999.



Fig. 4.15 Filled den, or 'set', of a family of badgers (photo: RAAP).

Rabbits live in groups. For their warrens they prefer softer, well-drained slopes such as burial mounds and embankments. Depending on the type of soil the tunnels in a warren can be between 5 and 250m long and 10 to 15cm across. The depth varies from 75cm below the surface (i.e. below frost level) to 4.5m in exceptional cases (Table 4.2).¹⁷¹ Rabbit warrens can cause (archaeological) soil subsidence. For example National Monument 45.947, a burial mound, required consolidation to prevent further subsidence caused by rabbit activity.¹⁷² Rabbit colonies will also clear the area around their warren of vegetation, and together with their burrowing this leaves the soil susceptible to erosion.¹⁷³

Badgers live in extensive dens (also called sets) they have dug themselves.¹⁷⁴ One set usually has three to ten entrances (although up to eighty have been reported) and consists of chambers linked by corridors that can be hundreds of metres long (Fig. 4.15). When inside their own territories badgers also dig refuges, simple holes in slopes, escarpments (e.g. Barrow 7, Oss-Paalgraven¹⁷⁵) or ditch sides where they

can hide in the event of danger. Badger tunnels are 25cm to sometimes 60cm across, and the subsurface depth of an entire badger set can be 1 to 4m.¹⁷⁶ Over the course of many generations a set often expands into a huge subterranean complex of corridors which sometimes cover a full hectare (Fig. 4.15).¹⁷⁷ Clearly badgers can inflict serious damage to archaeological remains above and below ground.¹⁷⁸ However, badgers are a protected species in the Netherlands; chasing them away to another location is therefore not an option. Foxes also dig dens comprising one or several tunnels 25 to 30cm across. Often existing (rabbit) tunnels are enlarged,¹⁷⁹ and sometimes an abandoned badger set will be used. Pre-existing damage by rabbits or badgers can thus be compounded by fox activity.

Like badgers, beavers are also a protected species and cannot be chased away or killed. These remarkable animals live either solitary or in small family groups along streams or lakes in territories that are anything from 100m to 3km across. Depending on the elevation of the water's edge and on whether the nearby water is

¹⁷¹ Dunwell & Trout 1999; Barton 1992.

¹⁷² Datema 2015.

¹⁷³ Dunwell & Trout 1999.

¹⁷⁴ www.zoogdierveniging.nl.

¹⁷⁵ Datema 2015.

¹⁷⁶ Dunwell & Trout 1999; www.zoogdierveniging.nl.

¹⁷⁷ *Ibid.*

¹⁷⁸ English Heritage 2000; Datema 2015.

¹⁷⁹ Dunwell & Trout 1999.

stagnant or flowing, beavers build their lodges either on land or in water, sometimes in combination with dams to regulate the local water level. Alternatively they may make their lodge in a high river bank, digging long tunnels 35cm across. Beaver lodges built in (artificial) ponds form small islands in the middle of the water. At present a beaver family is living on a section of the scheduled national monument De Ravage, a ship's wreck near the town of Almere, fortunately without causing any damage.

5 Damage resulting from human action

5.1 Introduction

Studies in the Netherlands, the UK, Germany and Belgium have indicated that the two main risk factors relating to land use, land management and development that are responsible for irreparable damage to archaeological sites are forestry and tillage.¹⁸⁰ In the Netherlands a third factor should be added,

the drainage of large swathes of land for the benefit of agriculture and groundwater extraction. Since the 1950s the groundwater table in much of the Netherlands has fallen 20 to 40cm on average, causing extensive desiccation of a large section of the archaeological soil archive.¹⁸¹ Most agricultural techniques that are potentially harmful to the archaeological soil archive were introduced during the intensification and upscaling of the Dutch

Table 5.1 Overview of interventions.

Interventions	Examples
1. Construction	
1.1 Site preparation and clearing	Raising, lowering, compacting, levelling (Temporarily) lowering the water table by means of well-point drainage
1.2 Building/renovation	Excavating construction trenches Piling Shallow foundations (slab-on-grade or strip) Jet grouting
2. Surface infrastructure	Cable and pipe trenches Sewage pipe installation/replacement Site excavation and placement underground skips
3. Surface infrastructure	Roads/motorways, parking lots, public squares Viaducts, ramps Wind turbines Solar plants
4. Development and maintenance built environments, both public and private	Excavation prior to renovation, foundation repairs, underfloor heating Planting/maintenance public green Digging ditches, ponds, bioswales Planting ornamental trees and shrubs
5. Nature creation and management	Cutting/uprooting trees and shrubs Removing the turf/nutrients Removing wildshoots
6. Agriculture: animal husbandry, pasture, arable and vegetable farming, forestry	Soil preparation Cultivation Manuring, crop protection Harvesting
7. Water management	Lowering the surface water table (pumping) Digging watercourses Digging, widening or dredging watercourses Shoring Groundwater extraction

¹⁸⁰ For British examples see Hinchcliffe & Schadla-Hall 1980; Darvill & Fulton 1998; Oxford Archaeology 2002; Trow & Holyoak 2008; Trow 2010; English Heritage 2010; Belgium: De Bie, Van Gils & De Wilde 2008; the Netherlands: Eerden & Van Heeringen 2000; Lascaris 2019; Germany: Behm 2000; Kretschmer & Mündel 2015.

¹⁸¹ Wijmer 1990; Van der Gaast & Massop 2005; Werkgroep NHV 2016.

agricultural sector, starting in the early 20th century and especially from the 1950s onwards.¹⁸² While many farmers have undoubtedly benefited from deeper forms tillage, those same soils are also important from an archaeological and cultural historical perspective. Many aspects of commercial forestry (production forests), such as tree cutting, removing and transporting the timber, and preparing the soil for replanting and fencing, also have an impact on the soil.

The increasingly urbanized setting of archaeological national monuments is characterized by potentially disruptive activities, usually in the context of building projects and the construction of surface and subsurface infrastructure. Legislation has long shielded archaeological national monuments in these areas against encroachment. As a result, monuments are often the last remaining 'vacant' plots in an otherwise urbanized environment. Today, however, they are under intense pressure

not only from project developers and local administrations but also from locally initiated public projects involving playgrounds or visualization of the past.

This is why many interventions on archaeological national monuments are subject to a monument permit (Section 2.5), to prevent highly disruptive or damaging actions or those that could detract from the experience value of a visible monument. This legal requirement does not solve all problems, however. In the province of Zeeland, grazing cattle leaves deep tracks on the slopes of mottes which thus become susceptible to erosion.¹⁸³ On sandy soils in the former peat extraction areas of Groningen and Drenthe wind erosion is increasingly becoming a problem, one of the causes being a recent ban on the spreading of manure slurry on fallow fields, a practice which used to control erosion to some extent. On the hills in the province of Zuid-Limburg every rain shower washes away a quantity of the fertile loess soil, because the

Table 5.2 Affected depths and frequencies for different primary soil preparation and soil improvement techniques.

Type	Affected depth	Frequency
	cm - GL	
Direct sowing	0	Once a year
Minimal soil preparation	5-7	Once a year
Seedbed preparation	10-15	Once or twice a year
Spading/turning	25-35	Twice or three times a year
De-compacting	25-35	Once, twice or three times a year
Cultivator/tine harrow	15-35	Once or twice a year
Grassland ripping/ploughing	20-30	Once every three to five years
Ploughing	22-35	Twice or three times a year
Ploughing using a subsoiler and spader	35-40	Once a year
Planting machine, root system $\varnothing \leq 80$ cm	10-80	Once every three to eight years
Harvesting, backhoe bucket $\varnothing 45-55$ to 60-100cm	30-50	Once every three to eight years
Spader/chisel plough (asparagus/scorzonera cultivation)	40-100	At construction
Flat lifter/chisel plough/subsoiler	35-150	Incidentally, sometimes deeper
Field drainage furrows	30-70	Incidentally
Field drain with/without trench, every 6-15m	80-120	At construction
Ditches, 1 to >3m wide	100-250	Incidentally
Levelling/peeling	Unknown	Incidentally

¹⁸² Lascaris 2019.

¹⁸³ Van Heeringen 2007; Jaarverslag Rijksdienst voor het Oudheidkundig Bodemonderzoek 1986, 81 and 174; 1987, 62; 1988, 59.

(Data sources: Heunks 1995; Ten Broeke 2012; Reuler *et al.* 2014; Breimer & Seurer 2014; Massop & Schuiling 2017; agricultural tillage equipment companies Goudland/Buts Meulepas B.V, Lemke GmbH).

hedges and terraces which historically prevented this from happening have now been removed to facilitate modern tillage techniques (Section 4.2.1).¹⁸⁴ Several other harmful interventions – at least from the perspective of the archaeological soil archive – are common practice in nature conservation, such as topsoil removal to decrease the nutrient content and create (new) wetlands (Section 5.5).¹⁸⁵

5.2 Agricultural activities

5.2.1 Introduction

The current trend towards agricultural upscaling directly touches upon archaeological heritage. Upscaling is manifest in field enlargement, construction and byre expansion (often in combination with the construction of a manure cellar) and larger storage facilities, and in the modification of water management regimes. All these changes involve the deployment of increasingly heavy agricultural equipment. Furthermore, certain soil interventions on farmland that are part of regular agricultural practice nonetheless can have a disruptive effect on the archaeological soil archive.¹⁸⁶ Agricultural land may be incidentally subjected to deeper soil interventions, such as installing drainage infrastructure (Section 5.2.6) or removing unsuitable subsoil layers (see Table 5.2).¹⁸⁷ Often it is the combination of interventions which causes the disruption. Fruit cultivation for instance can have a negative impact on archaeological national monuments not only because of the planting holes and root action, but also because of the associated drainage infrastructure and deeper support structures.

5.2.2 Regular (primary) soil preparation

Regular forms of topsoil tillage (cultivation layer/plough soil) involve mixing in crop remains (e.g. stubble), weeds or animal manure, improving the water storage capacity, and loosening the soil to optimize root development. In non-organic farming, removing or breaking



Fig. 5.1 Ploughing a field (photo: Lemken 2017).

up compacted topsoil layers that are caused by vehicle traffic or ploughing are also part of primary soil preparation. The mouldboard plough is the standard tool for primary soil preparation but cultivators, chisel ploughs and soil levellers are also used.¹⁸⁸

Until a few years after the Second World War plough depth seldom exceeded 15 to 25cm. In fact, plough soil depth has remained more or less unchanged for centuries, and early-20th-century farmers did no more damage to archaeological features than their medieval predecessors had done before them. However, as farmers began to plough deeper archaeological remains and layers at those deeper levels were increasingly affected. And whereas farmers usually feel some attachment to their land and the soil that sustains them, today's agricultural contractors tend to have

¹⁸⁴ De Groot 2006. In Zuid-Limburg, an *Erosieverordening* ('erosion by-law') has been in place since 1989. Green zones intended to slow down erosion are being recreated in the landscape, as are water retention reservoirs. See Section 6.11.

¹⁸⁵ Chardon 2008.

¹⁸⁶ Mauro 2001; Oxford Archaeology 2002; English Heritage 2004; Terwan & Ringers 2004; Louwagie *et al.* 2005; ITADA 2006; Oxford Archaeology 2010, 11 ff.; Deutsche Bundesstiftung Umwelt 2011. Landesdenkmalpflege Baden-Württemberg 2013; Reuler *et al.* 2014; Kretschmer & Möndel 2015; Lascaris 2019.

¹⁸⁷ For a list of the affected depth and surface of different tillage techniques in use in the Netherlands, Belgium, and Germany, see Heunks 1995, 52; Reuler *et al.* 2014; Willemse 2019; Louwagie *et al.* 2005, 91-108; Behm 2000.

¹⁸⁸ Reuler *et al.* 2014; Lascaris 2019.

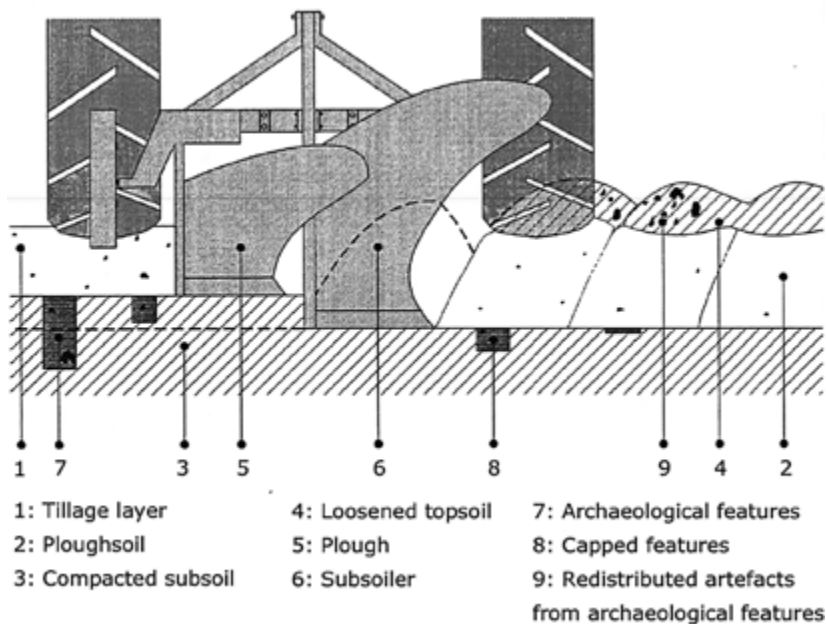


Fig. 5.2 Process, affected depths, and impact of (deep) ploughing (after Heunks 1995).

fewer scruples. Contracting firms are less inclined to account for unfavourable soil conditions during wet periods, with deeper rutting and ploughing as a result. In recent years, however, a move towards less invasive forms of tillage has been emerging.

The impact of the most common forms of tillage on underlying archaeological remains is undisputable.¹⁸⁹ All features and stratigraphy within the affected soil volume will be lost, and with it any associated artefacts and other remains (Fig. 5.2).¹⁹⁰ Ploughing and turning will transport archaeological remains such as pottery which until then were embedded in underlying features into the plough soil, where they are exposed to decay under the influence of mechanical and biological processes.¹⁹¹ Fragile inorganic artefacts such as (pre)historic pottery and ceramic building elements (e.g. roof tiles) can rapidly disintegrate and be destroyed. Studies of the changes which affect artefacts circulating in the plough soil have revealed the following:¹⁹²

- Pottery is increasingly fragmented the longer it circulates in a regularly ploughed topsoil;
- After five rounds of ploughing, 50% of artefacts originally contained in the subsoil will have been on the surface for some time

and exposed to mechanical degradation processes such as frost and expansion/shrinkage cycles; after ten rounds, this increases to 75%;

- After only one winter, soft and moderately porous pottery fired at low temperatures will have degraded to the point where the next intervention will destroy it;
- After eight years of unchanged cultivation half the metal artefacts will be damaged.¹⁹³

More robust materials such as flint or more intensely fired pottery such as stoneware will fragment more slowly. Copper, copper alloys such as bronze and brass, and other non-ferrous metals are also reasonably safe from (bio) mechanical degradation while in the plough soil, because the patina which usually covers such objects will protect them from corrosion.¹⁹⁴ They are however susceptible to physical damage from tillage.

Tillage erosion

A mouldboard plough moves the soil mainly in a vertical direction, but there is also some horizontal displacement. Studies have demonstrated that after three years of mouldboard ploughing soil has been moved horizontally over a distance of between 0 and 90cm, and in exceptional cases even up to 10m.¹⁹⁵ Other types of tillage, such as turning, can also move the soil over a distance of several metres.¹⁹⁶ On slightly uneven terrain the gradual displacement of part of the cultivation layer will slowly erase the local relief and thicken the plough zone.¹⁹⁷ Ultimately the top section of an archaeological level may thus be absorbed into the plough soil.¹⁹⁸

Given enough time, ploughing, turning and harrowing will all level out a terrain, but the effects of ploughing become apparent much more quickly.¹⁹⁹ As the soil is redistributed the terrain will be levelled and local (micro)relief disappears. The extent of this effect depends among other things on its direction.²⁰⁰ The levelling effect of ploughing parallel to the slope is less than when the field is worked from top to bottom.²⁰¹ The impact on local relief can be significant. Thirty plough movements are enough to reduce differences in elevation by several decimetres.²⁰² The resulting uneven thickness of the plough soil renders sections of

¹⁸⁹ Dunnell & Simek 1995; Oxford Archaeology 2002; English Heritage 2010; Trow 2010; Möllenberg & Schlichtherle 2013; Lascaris 2019.

¹⁹⁰ See also e.g. Darvill & Fulton 1998.

¹⁹¹ See e.g. Reynolds & Schadla Hall 1985; Dunnell & Simek 1995; Van Muysen, Van Oost & Govers 2006; Dain-Owens *et al.* 2013; Lascaris 2019.

¹⁹² For studies of the mechanical degradation of materials, see Pendleton 1999, 63; Reynolds 1987; 1989, 25-26; Clark & Schofield 1991; Richards 1985; Dobinson & Denison 1995, 52; Oxford Archaeology 2010, 8 and supplements 1, 2 and 3; Dain-Owens *et al.* 2013, 1184; Leskovar & Bosiljkov 2016; Noble, Lamont & Masson-Maclean 2019.

¹⁹³ Oxford Archaeology 2002, 7; Haldenby & Richards 2010, 1160; Lamont & Masson-Maclean 2019.

¹⁹⁴ Van Os *et al.* 2014.

¹⁹⁵ Van Muysen, Van Oost & Govers 2006.

¹⁹⁶ Spandl *et al.* 2009.

¹⁹⁷ E.g. Gillijns *et al.* 2005.

¹⁹⁸ E.g. Van Heeringen, van Kregten & Roorda 2003; Van Heeringen & Theunissen 2006; 2007; Huisman & Mauro 2013, 39.

¹⁹⁹ *Ibid.*

²⁰⁰ Meuwissen 2012.

²⁰¹ De Alba *et al.* 2004.

²⁰² Heckrath *et al.* 2006.



Fig. 5.3 Adorp-Munniketocht. Ploughed field; the slight elevation in the background is a small, completely ploughed-over terp (National Monument 45.062, photo: Jos Stöver/erfgoedfoto.nl).

the underlying archaeological levels vulnerable. Furthermore, levelling obviously also affects the surface sections of archaeological and cultural historical objects such as terps, mottes, dikes, raised fields, and burial mounds (Fig. 5.3).

Tare weight soil

The regular harvesting of grass sods as part of grass sod farming is yet another activity that will gradually strip the topsoil. In sod farming the adhering soil is part of the product; each harvest, up to 4mm soil is removed, adding up to several centimetres each year.²⁰³ If this loss is not compensated the repeated lowering of the ground surface across the field will reduce the underlying undisturbed layer, and every year any archaeology in it will be truncated a little more.

The adhering soil that is removed during harvest is called tare weight soil. The extent of this drop in the surface due to tare weight loss ranges from 0.1mm annually for seed potatoes

to 0.9mm for carrots, depending on soil type.²⁰⁴

In sugar beet cultivation no less than 10% of the total harvested weight can be tare weight soil. It can take decades before the plough soil actually becomes deeper as a result. After a potato harvest the adhering/tare weight soil is often placed back, but not always on the same field it came from. Because archaeological objects may thus end up in different locations than where they belong, soil archives may become distorted.²⁰⁵

5.2.3 Occasional tillage: deep and shallow levelling

Fields can be levelled to various degrees, from superficially scraping the topsoil to completely erasing all relief. The purpose of levelling is usually to prevent damage due to excess water or drought by creating a homogeneous and level cultivation layer.

²⁰³ Reuler *et al.* 2014; Lascaris 2019.

²⁰⁴ Reuler *et al.* 2014.

²⁰⁵ Fred Brounen, Cultural Heritage Agency of the Netherlands, oral communication.



Fig. 5.4 Cultivator or 'subsoiler', reaching a depth of c. 65cm (photo: Lemken 2017).

To prevent the plough soil from mixing with poorer subsoil and to preserve the cultivation layer, levelling is often combined with deep ploughing. First the higher sections, where excess soil needs to be removed, are deep-ploughed. Next, the now exposed poorer soil is relocated to lower areas, using levelling and scraping equipment. Finally, these lower sections are also deep-ploughed so that the original plough soil re-emerges and the added poorer soil is buried.

Both deep and shallow levelling will completely erase local micro-relief. A 1997 study concluded that since the 1950s the Netherlands has lost a staggering 25% of its relief.²⁰⁶ This process continues to the present day; in fact, micro-relief on agricultural land is probably being destroyed more rapidly and on a larger scale than in 1997.²⁰⁷ Levelling destroys any natural differences in elevation as well as (micro) relief formed during centuries of land use.²⁰⁸

In most cases levelling, both deep and shallow, also affects national monuments where archaeological remains occur just below the surface, such as the Late Neolithic sites in the region of West-Friesland (e.g. Aartswoud). The temporary removal of the cultivation layer completely destroys the relation between archaeological material in the plough soil and underlying archaeological phenomena. Deep

ploughing is disastrous for virtually all types of archaeological remains; only very deep features/constructions such as wells or waterholes will be preserved. Because of its huge impact levelling is not allowed on most archaeological national monuments.

5.2.4 Occasional soil preparation: decompaction

The intense and year-round traffic of heavy equipment on agricultural fields (but also in forests and nature areas) exerts a tremendous pressure on the subsoil.²⁰⁹ On top of that, in the past thirty years growing specialization and the delegation of farm work to contracting firms have led to the introduction of heavier machinery in both agriculture and forestry.²¹⁰ Despite the increase in tire and track width and size to compensate for vehicles' growing weight the strain on the soil has become worse.²¹¹ The result is soil compaction: the compression of soil components under strain, resulting in greater soil density and greater resistance to penetration, as well as a reduction in the total volume of pores (especially micropores) (Section 6.10).²¹² (Autumn) ploughing of soils in wet conditions will also cause distortion and ultimately compaction in the form of a denser and thicker plough pan down to a greater depth.

Because soil compaction in farming and forestry leads to water damage and diminishing yields, it is standard agricultural practice to prepare the soil every year to a fairly great depth (30 to 35cm) to loosen compacted soil prior to sowing next year's crop.²¹³ Even deeper interventions are used to break up compacted layers below the plough pan (Fig. 5.5). In this procedure, called decompaction, a spader breaks up 60 to 100% of the compacted layer to a depth of c. 30 to 40cm -GL (Table 5.3).

The occurrence and frequency of these regular (and deeper) forms of soil preparation vary greatly per soil type, region and farmer, so that their impact on the soil archive is equally variable.²¹⁴ What is clear however is that regular soil preparation techniques to counteract compaction can disturb archaeological features

²⁰⁶ Dijkstra *et al.* 1997.

²⁰⁷ Lascaris 2019, 18.

²⁰⁸ Oxford Archaeology 2002; Koomen & Exaltus 2003; Meylemans, Vanmontfort & Van Rompaey 2008.

²⁰⁹ Godwin *et al.* 2010; Van den Akker *et al.* 2013; D'Hose *et al.* 2017; Lascaris 2019, 15; Huisman & Ngan-Tillard 2019, 6-8.

²¹⁰ Heunks 1995; Hanegraaf & de Visser 2003; Oxford Archaeology 2002, 2010; Sukkel & Pulleman 2016.

²¹¹ Oxford Archaeology 2010; Dain-Owens *et al.* 2013.

²¹² Bassett & McDaniel 1967; Oxford Archaeology 2002; De Vos 2005; Godwin *et al.* 2010. At present, nearly half of the Dutch subsoil exceeds the critical limit for density, and both the total affected area and the degree of compaction are expected to increase further (Van den Akker *et al.* 2013).

²¹³ Reuler *et al.* 2014; Willemse 2019.

²¹⁴ Lascaris 2019.

and artefacts that are just below the plough soil, mixing objects and features and rendering them increasingly more susceptible to erosion.²¹⁵

5.2.5 Incidental soil preparation: soil profile improvement

Soil profile improvement often includes breaking up or turning over stagnating/compacted subsoil layers. Such layers can be formed by (secondary) compaction due to heavy traffic or certain agricultural activities, for instance harvesting under wet conditions (see above).²¹⁶ Unsuitable layers can also occur naturally as changes in soil texture, or as iron pan (Fig. 5.5). Countermeasures often involve the removal or disruption of the unwanted layer by means of (deeper) soil preparation techniques such as the various forms of (deep) turning, deep ploughing, spading, or turning over with a rotary cultivator or a backhoe.²¹⁷ These special-purpose tillage techniques turn over the soil to a depth of 90 to 120cm. In the past this was common practice in waste land reclamation, for instance on heathland, and burial mounds and Celtic fields were destroyed in the process.²¹⁸ Today, soil profile improvement is still used in the horticultural sector, particularly for asparagus cultivation, and in orchards. Asparagus fields but also fields prepared for scorzonera or (fruit) trees are often worked quite deeply, sometimes down to 100cm -GL.²¹⁹

Soil profile improvement can completely destroy archaeological remains as the practice damages layers which would have been largely unaffected by ordinary ploughing (Fig. 5.2). Like primary soil preparation, soil profile improvement will also truncate archaeological levels.

5.2.6 Effects of drainage infrastructure and field ditch excavation

Drain construction poses a physical threat (cutting, displacement) depending on which methods are used. If the drains are to be placed in trenches the immediate (physical) threat to archaeological remains is not limited to the



Fig. 5.5 Profile trench on an arable field near the Lonnekermeer nature preserve, showing three compacted layers: 1) dense plough pan (due to heavy traffic) with stagnating water (30-35 cm -GL); 2) hard, impermeable iron pan (45-55 cm -GL); and 3) a loam-rich layer (55-65 cm -GL) (photo: Joris Schaap, Badus Bodem & Water).

excavation of those trenches. The weight of the heavy equipment involved (up to 20 tonnes) can crush vulnerable archaeological materials such as pottery and glass (Section 5.3.4), and the digging itself will scatter objects and destroy the association of features, artefacts, and layers. If no trenches are necessary, these secondary effects will not occur. For trench-less drains a specialized, v-shaped cutter (Fig. 5.6) cuts two narrow slots and lifts the narrow strip of soil in-between (10-20cm thick) to insert the drain. The impact of the procedure on archaeological remains is limited.

The excavation of ditches of various sizes will also disturb and dislocate archaeological remains. The disruption caused by field drainage

²¹⁵ De Vos 2005.

²¹⁶ Söhne 1953; Boels & Havinga 1974; Hanegraaf & De Visser 2003; Ten Berge & Postma 2010, 42 ff.; Zwart *et al.* 2011.

²¹⁷ Heunks 1995; Zwart *et al.* 2011.

²¹⁸ Lascaris 2019.

²¹⁹ E.g. Ten Broeke 2012; Reuler *et al.* 2014.



Fig. 5.6 Trench-less insertion of a drainage pipe by means of a V-shaped soil cutter (photo: Smits B.V., Veldhoven).

furrows is limited, certainly if they do not extend beyond the plough soil, although their presence may complicate the identification of (often poorly) visible archaeological structures that manifest themselves as micro-relief. A second factor with regard to ditches is that they require regular cleaning; when sludge is dredged up from the bottom smaller or larger quantities of untouched soil can be accidentally scooped up as well. If this happens, archaeological remains that were already affected when the ditch was dug will be damaged further. As the sludge is usually spread out over the field, any objects caught in it may end up scattered on the surface.

5.2.7 Topsoil inversion

Topsoil inversion is the wholesale replacement of existing topsoil with another type of soil so as to render the field suitable for a new type of crop.²²⁰ This is how in the north of the province of Noord-Holland and in the district of Noord-Kennemerland several thousand hectares of grassland and other areas with clay-on-sand have been and are still being adapted for flower bulb cultivation. In this procedure the existing plough soil is partly removed and the underlying sand is brought to the surface, after which the plough soil is redeposited. Such soil

removal activities are often combined with levelling, lowering the surface, or deep ploughing. Clearly these activities have a disastrous impact on the archaeological significance of the affected areas.

5.2.8 Uprooting trees and shrubs including adhering soil

Tree farming and orcharding also affect the soil beyond the cultivation layer. Young trees with their root balls (25/30cm to 80cm across) are positioned by a mechanical planter into evenly spaced, pre-dug holes. Uprooting or moving trees also involves the use of a machine/backhoe, which pulls them out of the ground, root, soil and all. Some backhoe buckets measure 10 to 55cm across, but buckets of 130, 160, 200 and even 260cm are also available.

The impact of tree farming on an archaeological site varies.²²¹ Long-term tree farming on the same field will completely homogenize the soil down to the depth of the planting holes. Drained fields are susceptible to a drop in the local groundwater table and to desiccation, which may adversely affect fragile materials (see Section 5.4.7).²²² Furthermore, the volume of tare weight soil in tree framing far

²²⁰ Lascaris 2019.

²²¹ Reuler *et al.* 2014; De Vries *et al.* 2016.

²²² Cox *et al.* 2001.

exceeds that produced by regular arable farming, with an estimated annual drop in surface level of c. 6 to 7mm.²²³ As a result the cultivation layer will gradually extend deeper into the ground and underlying archaeological levels will be truncated.

5.2.9 Grazing and hay production

In the UK, grazing is considered the most archaeology-friendly form of agricultural land use.²²⁴ Cattle grazing is the only activity on meadows and usually only requires superficial topsoil improvement, the damage of which will be limited.²²⁵ The main forms of soil disturbance that can be expected in this type of agricultural land use are:

- Trampling of the vegetation and the soil by livestock;
- Rutting by agricultural vehicles;
- Construction and maintenance of drains and ditches;
- Building new fences or excavating watering holes;
- Grassland improvement by manuring or re-sowing.

Grazing can take many different forms (e.g. continuous, seasonal, rotational), and the effects of each on the degradation of archaeological remains varies.²²⁶ Wet or dry weather stimulates trampling and erosion (on slopes).²²⁷ Livestock often follows a set route along a fence, along a field track, or towards feeding and watering places, with local disturbance of soil and vegetation as a result. Rutting by agricultural vehicles is particularly a problem on waterlogged soils.²²⁸

The impact of several aspects of grazing on archaeological remains is uncertain. One of these is nitrate leaching. Nitrate leaching out of manure is more intense when livestock is being grazed but its effect on archaeological materials appears to be limited and gradual (Section 5.2.13).²²⁹ Furthermore, grassland is a more attractive habitat to many soil-living organisms than arable fields or forest, and their presence will increase bioturbation.²³⁰ However, these effects also seem to be limited. As long as

grassland bioturbation is contained within the cultivation layer any additional negative effect on archaeological information carriers will be minor.

A trend with potentially negative consequences for the archaeological soil archive is the conversion of pasture to silage/hay production. On a traditional dairy farm grassland combined these two functions. The shift towards fodder production whereby livestock is kept indoors for most of the year has changed land use. Fast-growing grass varieties and the application of additional fertilizer have made it possible to upscale from three or four annual harvests in the 1960s to five or six harvests today. To optimize the yield fields are ploughed or turned more regularly in order to improve moisture and oxygen conditions.²³¹ Other potential activities are levelling followed by re-sowing in order to achieve a more even sod (relevant in the context of current manure legislation), or lowering the groundwater table when necessary.²³² The associated intensification of vehicle traffic and soil interventions causes rutting and compaction, fragmentation and crushing of artefacts, and possibly also a truncation of archaeological levels.

5.2.10 Conversion of grassland into arable.

Once grassland within the boundaries of an archaeological national monument has been converted into arable the underlying archaeology there will be more at risk of mechanical and chemical damage.²³³ Besides the regular soil interventions specific to arable, activities carried out to prepare the new field (drainage, road construction) can also be disruptive.²³⁴ In addition lowering the groundwater table is often part of the conversion to arable, which affects soil moisture and the conditions for preservation of archaeological materials (Section 5.4.7).²³⁵

²²³ Reuler *et al.* 2014.

²²⁴ English Heritage 2004.

²²⁵ Heunks 1995; Reuler *et al.* 2014.

²²⁶ *Ibid.* Continuous: livestock is allowed access to the same grazing area throughout the year. Seasonal: livestock is grazed in a particular area for only part of the year. Rotational: the range is divided into several pastures, each being grazed in sequence throughout the grazing period. Several other systems exist.

²²⁷ Jones, Harlow & Gosling 2002, 31;

Russell 2003; English Heritage 2004.

²²⁸ See also Van der Heiden, van Doesburg & Stöver 2017.

²²⁹ Van den Pol-Dasselaar, De Haan & Philipsen 2013.

²³⁰ Babel 2003. See also Van Heeringen & Theunissen 2002.

²³¹ Heunks 1995.

²³² Van Eerden 2004.

²³³ Oxford Archaeology 2002; Trow 2010;

Behm *et al.* 2011; Dain-Owens *et al.* 2013.

²³⁴ Oxford Archaeology 2002.

²³⁵ Lascaris 2019.

5.2.11 Land use in the context of greenhouse farming

In the Netherlands the total area dedicated to greenhouse farming has been expanding for years. Between 1996 and 2015 the increase amounted to 2,450ha.²³⁶ The impact of this development on archaeology relates first of all to the activities associated with greenhouse construction. As a rule the site is levelled prior to construction, and in many cases extensive irrigation and drainage systems are installed as well.²³⁷ Most greenhouse types are based on a steel construction which rests on a concrete foundation which in some cases requires piling, often skin-friction.²³⁸ Modern greenhouses have a more robust construction than in the past because today's greenhouses are exposed to greater forces due to their extra height, the presence of a screen below the glass cover, or overhead cultivation appliances, and also due to higher storm resistance standards, which call for thicker beams and extra buttresses.

The main impact on archaeological remains besides mechanical, construction-related effects (digging, piercing, displacement) is the effect the presence of a greenhouse will have on the groundwater situation. For example, beneath a hard floor, reducing conditions will start closer to the surface and blue-staining may occur (Section 5.3.6). In greenhouses without a hard floor surface the opposite effect can be observed as soil moisture can evaporate but is not replenished by precipitation. The soil moisture content will therefore be reduced, causing aerobic processes of decay at deeper levels. This may explain why Roman-era wooden piles observed in an excavation trench inside a greenhouse on top of the archaeological national monument of Matilo had disappeared to a considerable depth within a ten-year period.²³⁹

²³⁶ Centraal Bureau voor de Statistiek ('Statistics Netherlands') 2016: Mutatiereeks Bodemgebruik 1996-2015.

²³⁷ Heunks 1995.

²³⁸ www.agriholland.nl/dossiers/kassenbouw/standtechniek.html.

²³⁹ Brandenburg & de Bruin 2016, 235-237. This report also mentions an alternative explanation, a possible correlation between the deeper impact of aerobic conditions below the greenhouse, and the simultaneous construction of the Roomburg housing development. The lower groundwater table which resulted from this event may have affected organic remains outside the greenhouse as well.

²⁴⁰ Kortlang 1987.

²⁴¹ Haan *et al.* 2009.

²⁴² Eghball 2002.

²⁴³ Nord, Mattsson & Tronner 2005; Huisman 2009.

²⁴⁴ Pollard *et al.* 2004; Ward, Smith & Lawley 2009. The possible negative effects of manuring on metal corrosion in artefacts in the cultivation layer were discussed as early as the 18th century (Tymann 1996). See also Mattson *et al.* 1996; Meeussen *et al.* 1997; Nord, Mattson & Tronner 1998; Nord *et al.* 2000; Soonius, Bekius & Molenaar 2001.

5.2.12 Silage pit construction.

Harvested fresh fodder is often stored in silage pits for winter use. In fact these constructions are not pits but rather stacks of fodder piled on top of a hard sunken floor surface and covered with agricultural sheeting, sometimes with a layer of sand on top. If sand is used it is dug out on both sides of the silage pit, creating trenches that tend to reach well below the cultivation layer. The negative impact of each single silage pit on the soil is limited, but because silage pits are regularly moved the effect is cumulative.²⁴⁰ It is also quite common for several pits to be constructed side by side, and together they constitute a considerable disruption of the soil surface. Cutting and transporting the silage is accompanied by intense vehicle traffic, which renders the immediate area susceptible to damage due to rutting and compaction.

5.2.13 Eutrophication, acidification, and liming

Eutrophication

In modern agriculture it is common practice to apply large quantities of animal manure to grassland and maize fields to dispose of surplus manure produced by soil-bound dairy farming and indoor bio industry. At present manure is mostly injected into the soil every 20cm to a depth of 5cm.²⁴¹ The effect of these modern manuring methods on soil structure is negligible. Virtually all organic matter is mineralized and ammonium is converted into nitrate and absorbed by plants.

Manure tends to be alkaline due to the presence of ammonium.²⁴² The effect of manuring on archaeological remains is uncertain; copper/copper alloy objects (e.g. bronze) are affected mainly by acidic soils.²⁴³ The assertion, made in studies published in 2004 and 2009, that manuring speeds up the rate of decay of metal objects is therefore probably incorrect.²⁴⁴ Such decay seems rather to have been caused by the present intensification of soil preparation interventions, which tend to remove

the objects from their protected environment into the cultivation layer.²⁴⁵ Even if manuring were to have a negative impact there are significant differences between the different types of manure:

- Minerals from animal manure are slowly released, and current manuring regulations stimulate their optimal absorption into the crop. The risk of damage to metal objects is smallest in the case of unprocessed manure (solid stable manure), which has a relatively low ammonium content and a high phosphate content.
- Minerals from chemical fertilizer are quickly released and usually contain more salts.

Manuring can also have other, physical effects on archaeology; in the past some fields (and even woodland) were deep ploughed so as to increase the soil's capacity to absorb excess manure.

Acidification

Bone is prone to rapid decay in permeable, well-oxygenated, acidic soils if the calcium buffering capacity decreases,²⁴⁶ and also plant fibres are negatively affected by acidic conditions.²⁴⁷ On the other hand, according to Pennington (1996) pollen tends to be better preserved in acidic soils (pH ≤ 5.5) because the acidity slows down decay by micro-organisms.²⁴⁸ This also applies to other ecological remains in archaeological contexts. Many non-carbonized organic remains (wood, seeds, leather, animal-based textile fibres) tend to survive better in relatively acidic (and anaerobic) soil conditions.²⁴⁹

Reduced soil acidity appears to have little effect on archaeological remains, and the process is a slow one.²⁵⁰ A study of the degradation of the soil archive at the Roman fortress of Fectio, a scheduled monument, has produced no indications that the degradation of non-ferrous metals has accelerated in the last fifty years due to changing soil acidity caused by acid rain or more intense manuring.²⁵¹ However, there is uncertainty as to whether the results of this study are applicable elsewhere, since the specific composition and texture of the archaeological layers and features as well as the site's clayey soils with their limited porosity and high lime content appear to have been contributing factors.

Liming

Soil acidification on arable fields and in nature areas is often controlled by means of regular liming in order to raise the soil pH.²⁵² In Germany lime is being ploughed into forest soils on a large scale, resulting in severe (mechanical) damage to buried archaeological remains. Peat soils are also highly susceptible to severe acidification and decreased fertility, which is why some farmers resort to regular liming. In theory, liming could also adversely affect archaeological remains because the resulting reduced soil acidity would stimulate microbial activity, which in turn adversely affects the preservation of non-carbonized organic materials.

Iron corrosion proceeds more slowly in an alkaline environment (e.g. one with a high calcium content), without ceasing altogether.²⁵³ Some researchers have suggested that an acidity above pH 6 has a negative effect on the preservation of fossil pollen,²⁵⁴ in which case a rise in pH would accelerate the decay of soil features and organic remains by microbial activity. Further research is needed before any definite conclusions can be drawn.²⁵⁵

5.2.14 Rock flour

Rock flour is a collective term for various types of ground volcanic rock. The constituent minerals of rock flour restore elements to the soil that for some reason have become depleted.²⁵⁶ Reactive minerals such as magnesium in rock flour and also the weathering of volcanic minerals such as olivine or plagioclase sequester CO₂ from the air as a carbonate. This raises soil acidity but also releases calcium and potassium, which can be used by plants.²⁵⁷ In other words, rock flour improves the soil but contains only little phosphate and no nitrogen, which is why it does not need to be included in fertilization accounts. This makes rock flour attractive to farmers.

Rock flour is used in nature conservation to improve acidic soils in which the buffering agents calcium and magnesium have been largely depleted. In these instances the purpose of applying rock flour is to restore the nutrient balance of grassland, heathland and forests on

²⁴⁵ Spandl *et al.* 2009.

²⁴⁶ Huisman 2009, 51.

²⁴⁷ Huisman 2009, 84, 98.

²⁴⁸ Kool *et al.* 2005; Brinkkemper 2006.

²⁴⁹ *Ibid.*; Huisman 2009.

²⁵⁰ Hans Huisman, Cultural Heritage Agency of the Netherlands, oral communication.

²⁵¹ Van Os *et al.* 2014.

²⁵² See e.g. Meeussen *et al.* 1997; Van der Zee *et al.* 2017.

²⁵³ Huisman 2009, 98.

²⁵⁴ Havinga 1971; Andersen 1986; Tomescu 2000.

²⁵⁵ Havinga 1967, 1971; Brinkkemper 2006.

²⁵⁶ Van Diggelen *et al.* 2019.

²⁵⁷ Bertil van Os, Cultural Heritage Agency of the Netherlands, oral communication.



Fig. 5.7 Dispersing 250 tonnes of rock flour over 25ha heathland and forest, province of Noord-Brabant (Strabrechtse Heide and Beuven), November 2018 (photo: P. van Schalen).

poor sandy soils. The buffering agents are released after weathering, which ensures a long-term continuous supplement rather than a temporary, short-term boost such as that which calcium provides. The volume of applied rock flour ranges from 10 to 16 tonnes per hectare (Fig. 5.7). Little is known about the effects of rock flour application to the surface of archaeological sites.

5.2.15 Impact of crop protection agents and biocides

We were also unable to find information on the impact of crop protection agents or biocides on archaeological remains. What is known, however, is that many of the agents currently in use end up in the soil, where they have a highly disruptive effect on soil organisms.²⁵⁸ One side-effect is that soils become denser in the absence of the aeration and porosity normally provided by soil organisms.

²⁵⁸ Pfiffner 2017.



Fig. 5.8 a: Construction of a solar plant with pile foundation near Hoofddorp (photo: SolarEnergyWorks 2017); b: Soil disturbed by rutting during the construction of a solar farm, Landkreis Straubing-Bogen, Germany (photo: Büttner & Husty 2015).

5.3 Building and construction activities

5.3.1 Introduction

In the past three decades urbanization has become the main driving force behind landscape change. Between 1950 and 2016, 550,000 hectares of formerly agricultural land were converted to make room for housing developments, business parks, and surface and

subsurface infrastructure (Table 5.3).²⁵⁹ In a built environment, several kinds of interventions have the potential to damage the archaeological soil archive: digging (utility) trenches or (sheet) piling can disturb the soil; the strain of road construction and renovation can lead to soil compaction, and cable and sewer trenches cause direct damage. Other interventions that follow in the wake of construction are also risk factors with regard to any archaeological remains present, such as the development and maintenance of gardens and parks, and alterations to existing buildings (e.g. extensions or cellars).²⁶⁰

²⁵⁹ Centraal Bureau voor de Statistiek ('Statistics Netherlands') 2017: *minder landschap meer bebouwing* ('Less landscape, more buildings') 1950-2015 (www.cbs.nl); See also Kuhn & Lau 2015; Weiss 2015; Lascaris 2019, 30.

²⁶⁰ Nixon 1998; Williams & Corfield 2002; Huisman *et al.* 2011a.

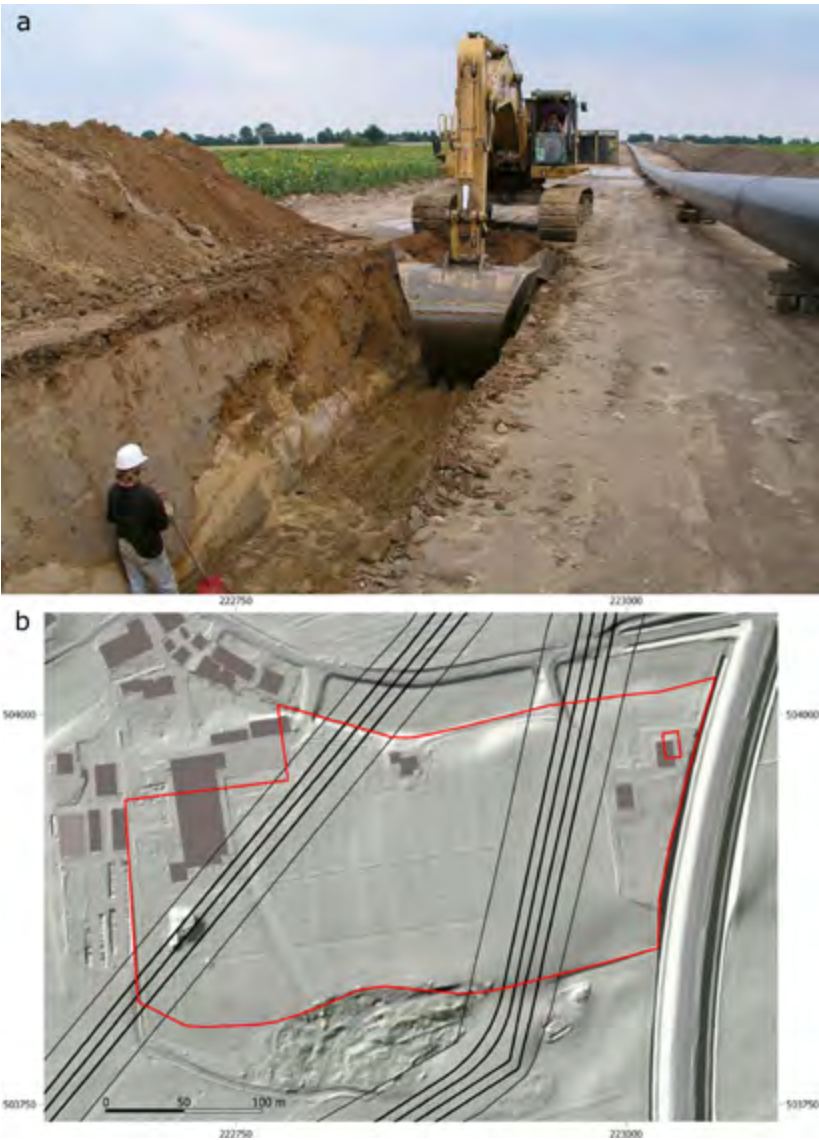


Fig. 5.9 a: Digging a trench for a natural-gas pipeline (photo: Lascaris 2019); b: National Monument 45.807 Varsen-Varseneres (in red) dissected by natural-gas pipelines (after Scholte Lubberink *et al.* 2017).

Due to current permit policies harmful construction activities on archaeological national monuments will be limited (Section 2.5). Nonetheless some activities do occur.

Zoning regulations may earmark certain scheduled areas for construction, for instance greenhouses, farmhouses, byres and barns (in agricultural areas). If an area was already designated as a building site under current zoning regulations, this constitutes current use and permit procedures must take this into account. However, any construction on a national monument is contrary to the basic principle of minimizing the disruption of national monuments and maximizing their potential for future research, and permits are therefore issued (conditionally) for such interventions only in specific situations.

Building and construction activities are discussed here only briefly; two previous publications by the Cultural Heritage Agency of the Netherlands, ‘De invloed van bouwwerkzaamheden op archeologische vindplaatsen’ (‘The Impact of Construction Activities on Archaeological Sites’, 2011) and ‘Handreiking archeologievriendelijk bouwen’ (‘Guideline Archaeology-friendly Building’, 2016) deal with this subject in more detail.²⁶¹

Table 5.3 Mutations in land use, 1996-2015
(data source: *Centraal Bureau voor de Statistiek, 2017*).

Land use	Surface (ha)		Decrease/ increase
	1996	2015	
			%
Traffic	109.438	115.563	5,3
Built-up	310.551	361.526	14,1
Semi-built-up	37.186	49.318	24,6
Recreation	91.503	105.418	13,2
Agriculture	2.336.951	2.236.317	-4,5
Woodland and open nature	478.000	498.956	4,2
Inland waterways	355.948	371.941	4,3

²⁶¹ Huisman *et al.* 2011a and Roorda & Stöver 2016, respectively. See also Huisman 2013; Bouwmeester *et al.* 2019; Historic England 2019.

The six most common interventions (Table 5.4):

1. Soil removal: e.g. building pits or trenches, soil profile improvement, road construction, watercourses, planting holes;
2. Piercing: (sheet) piling, grouting;
3. Strain: Compression and distortion of soil strata as a result of soil depositions, shallow-foundation constructions, or heavy vehicles;
4. Water extraction: changes in the ground-water system which alter the preservation conditions;
5. Covering the original soil surface;
6. Surface stabilization prior to construction.

Most construction projects involve combinations of these interventions. It is important to realize that the correlation between the degree of information loss due to

building and construction activities, and the extent of the intervention is not always proportional. Relatively limited interventions may cause a substantial loss of information, depending on site type, site size, and feature/object density.²⁶²

5.3.2 Soil removal

Building activities usually involve the removal of soil for construction pits and trenches for utilities and piping, but also for example to accommodate subsurface facilities such as basements, parking garages, skips and tunnels.²⁶³

Table 5.4 Construction-related interventions and effects.

Type of intervention	Intervention	Effect
1. Soil removal	Removal of loose cultivation layer, levelling (site preparation)	Soil transport (removal)
	Excavating construction pits, crawl spaces	
	Strip-foundation trenches	
	Trenches for frost-protected slab-on-grade foundation	
	Utilities trenches & holes	
	Digging planting holes trees/shrubs	
	Inserting pavement	
	Digging ditches, ponds, bioswales	
2. Piercing	(Sheet) piling	Distortion
	plaatsen damwanden	Soil mixing (displacement piles)
	Grout columns, grout anchors	Soil displacement (displacement piles)
	Sheet pile wall removal	
	Vertical drainage in added soil (sand column)	
3. Load	Soil deposition	Distortion
	Soil density improvement (site preparation, paving/metalling)	Compaction
	Heavy building traffic	Fragmentation/fracture
	Spread-footing foundation	
4. Water extraction	Pumping (groundwater)	Soil consolidation
	Drainage (Lowering the surface water table)	Desiccation: mineralization
5. Covering	Constructions (floors)	Blue staining
	Metalling/paving (e.g. roads)	
6. Stabilization	Subsoil reinforcement	Unknown: soil mixing under pressure (?)

²⁶² De Groot et al. 2011.

²⁶³ Huisman et al. 2011a, Section 3.3.1.



Fig. 5.10 Foundation piles of a demolished building visible in the profile of an archaeological trench at Voorburg (Forum Hadriani, National Monument 508.083). The pile has successively penetrated a clay deposit associated with the Roman harbour, a sandy layer, and a Neolithic peat layer. Impressions of cattle hooves are visible in the top of the peat layer. The impact of modern piling is evident in the sand; not, however, in the clay or peat layers.

or damaging its artefacts. The shallower subsurface archaeological remains and features are situated the more likely they are to be damaged by digging.²⁶⁴ Even a small excavation can lead to significant loss of information. Long utilities/pipe trenches may make it impossible in the future to connect features and stratigraphical layers in different sections of the monument, a process called site compartmentalization (see below).²⁶⁵

A negative side-effect of soil removal, particularly in soft soils or deep trenches, is deformation of the surrounding soil matrix as the ambient pressure drops.²⁶⁶ To prevent profile collapse while the excavation is ongoing, and also in cases where there is no room for a grass-covered embankment, a special construction will contain soil pressure. Common solutions are using a vibrating tool to insert steel sheets, and slurry walls. For slurry walls, a trench is first stabilized with a bentonite/water slurry before inserting a reinforcing cage which is filled with concrete.

Utilities/pipe trenches

The Netherlands has a vast and intricate network of underground pipes and utilities, also in rural areas. Many follow roads, but they can also run straight across the landscape (Fig. 5.9). In a built environment utility and sewer trenches are very common. The minimal depth of these trenches is often regulated; *Keur Waterschap Rivierenland* 2014 ('Rivierenland water board 2014 Ordinance'), for instance, stipulates that high-voltage cables must be placed at least 120cm deep, that water and gas pipes must be at least 100cm below the surface, and telecommunications cables at least 60cm. When canals and other open water is to be crossed there must be at least 100cm of soil between the utilities/pipes and the planned bottom of the water; this is called the 'soil cover' (*gronddekking*).

The average soil cover of the larger gas pipes in the Dutch gas transport network is 1.2m (regional network) or 1.75m (main network).

Digging activities physically disturb an archaeological national monument, destroying its features and stratigraphy and displacing and/

²⁶⁴ Roorda & Stöver 2016.

²⁶⁵ Willemsse 2015.

²⁶⁶ Korff 2009.

Other relevant variables with regard to pipes and cables, besides depth and soil cover, are their dimensions and those of the associated trenches.²⁶⁷ Trenches for electricity cables on solar farms and utilities trenches along roads (e.g. natural gas, telecommunications, electricity, water) are usually fairly narrow (50cm or less). Sewer trenches are much wider, and those for major gas transport pipes have a significant negative impact on the soil archive which often extends beyond the trench itself. Pipes with a large diameter require extensive sunken construction trenches which can be up to 20m wide and in the middle contain a much deeper, narrow trench for the pipe itself (Fig. 5.9). The constant traffic of very heavy-duty excavation equipment and pipe-transport vehicles in and around the construction trench causes severe soil disturbance, often down to several decimetres below the cultivation layer (preservation of the cultivation layer – which is later re-applied – is another reason for these extended construction trenches). After the work is completed, subsequent decompaction can cause yet more disruption. Pipe and utilities trenches have caused significant disturbance on archaeological national monuments, particularly in the past.²⁶⁸ Sometimes existing transport pipes are doubled or need to be replaced.

Site compartmentalization

Construction activities on an archaeological site may create a patchwork of isolated soil compartments,²⁶⁹ their limits defined by utilities and sewer trenches, ditches and canals; or by caissons, sheet piling, subsurface constructions, or various forms of surface cover.

Soil compartmentalization affects the original soil conditions in the different soil compartments, and any archaeological remains they contain will react to those changes. Although little research has been done on this specific type of physical threat, soil compartmentalization could potentially have a serious negative impact on monuments because



Fig. 5.11 Piercing archaeological remains (photo: Historic England 2019).

it alters the integrity of (originally larger) soil systems and weakens the site's original internal cohesion by destroying the wider context of features and objects. In the case of some complex types the disturbance of even a small section of the site (one or a few 'compartments') may render a much larger section illegible.

²⁶⁷ Lascaris 2019, 33.

²⁶⁸ See e.g. Scholte Lubberink *et al.* 2017.

²⁶⁹ Willemse 2015.

5.3.3 Piercing

The purpose of a foundation (for a building or other construction) is to transfer the load to a solid surface. There are three basic foundation types: shallow, skin-friction, and end-bearing. Shallow foundations use pre-existing constructions or else rest directly on the surface. Skin friction foundations use piled, relatively short piers whereby the load-bearing capacity is the sum of (mainly) the friction along the shaft and (to a lesser extent) the end resistance. End-bearing foundations are used when soil layers of a sufficient load-bearing capacity occur at great depth.

Which particular type is best suited depends on the design and the weight of the finished construction, the load-bearing capacity of the soil, and environmental aspects (potential nuisance; the presence of archaeology).²⁷⁰ Overall there are two types of pile foundation: soil displacement and soil replacement foundation columns. Within those two types it is possible to distinguish driven (piling, screwing,²⁷¹ vibrating, pushing) or on-site (jet)cast columns. The effect of each method on the surrounding soil matrix is roughly the same: mixing (to a greater or lesser degree), piercing, soil distortion, and soil displacement (soil-replacing piles) (Fig. 5.10).²⁷²

Jet grouting or pressure grouting is a foundation method that allows the construction of grout bodies (e.g. columns) with a large diameter (up to c. 1.5m) in all soil types, without vibrations or excessive noise. A mixture of water, sand and concrete is injected *in situ* into the soil under high pressure, where it will harden into a so-called jet-grout foundation column. Due to its irregular shape a jet-grout column also exerts an irregular pressure on the surrounding soil, and the high-intensity cutting action causes erosion along the full length of the grouting pipe. Some of the soil will therefore be washed up along the pipe; in the case of soft soil sections (e.g. local peat deposits) the impact can be extreme.

The greater a site's feature/object density the greater the potential loss of information (and by implication damage) that may result from piling (Fig. 5.11).²⁷³ Particularly at risk are small sites with object clusters, sites comprised of thick archaeological (artificial deposition) layers such as terps, or river dunes with settlement traces. Equally vulnerable are sites with extensive timber or masonry constructions such as revetments and foundations, for piling will cause fracture, displacement and distortion of those archaeological constructions and the surrounding soil.²⁷⁴ The removal of pile and sheet foundations is yet another potential source of disturbance.²⁷⁵ Even if the piles are allowed to remain in place, subsequent building activities will not only cause additional disturbance but the addition of more piles will also limit options



Fig. 5.12 Soil depot on archaeological national monument Beuningen-De Woerdjes (National Monument 45.299).

²⁷⁰ Huisman *et al.* 2011a; Roorda & Stöver 2016; Historic England 2019.

²⁷¹ Screwed piles are soil-replacing piles equipped with a screw thread, which can be 'screwed' into the soil without causing excessive vibrations or noise.

²⁷² Huisman *et al.* 2011a, Section 4.3; Huisman *et al.* 2011b; Roorda & Stöver 2016, 25; Historic England 2019.

²⁷³ See also Huisman *et al.* 2009a. In general an average foundation design will disturb no more than 2% of the surface of a site, especially if soil replacement piles are used.

²⁷⁴ Roorda & Stöver 2016, 26.

²⁷⁵ Groenendijk 2009.

for future archaeological research even further. For all these reasons the national government is extremely reluctant to allow construction activities on archaeological national monuments.

Vertical drainage

When a soil mass is deposited on top of soft soils (see Section 5.3.4) additional interventions may be carried out which have their own specific effect on the groundwater situation and the archaeological soil archive.²⁷⁶ One such intervention is vertical drainage, which in the case of a substantial added soil mass is done to mitigate the risk of collapse. An example of this type of drainage is pressing perforated plastic strips into the soil in a dense grid pattern; these strips will remain there. An alternative solution to ensure rapid drainage is using sand columns. The various types of vertical drainage have in common that interstitial groundwater is quickly removed, allowing a more rapid compression of the soil layers. This reduces the risk of subsidence or collapse and shortens the interval between the soil mass' construction and subsequent use. The effects of vertical drainage on the groundwater situation are temporary and will stop when sufficient water has been removed to achieve a new state of equilibrium.

5.3.4 Load

Three types of load can be expected to occur during construction activities: the weight of shallow-foundation structures, the addition of a (temporary or permanent) surface soil mass, or the weight and traffic of heavy-duty machinery. Natural loads are also possible, such as the pressure of a clay deposit on an underlying peat soil, or as a result of soil maturation.²⁷⁷

The effects of an added load (artificial or natural) on soil layers may vary. The main effect is soil compaction, which occurs when the soil below the centre of the added mass is compressed (compacted). Soil pressure increases, all soil components (soil particles, objects, cables and pipes) move downwards, and stratigraphic layers become thinner. In the margins of a load, and also in cases where the

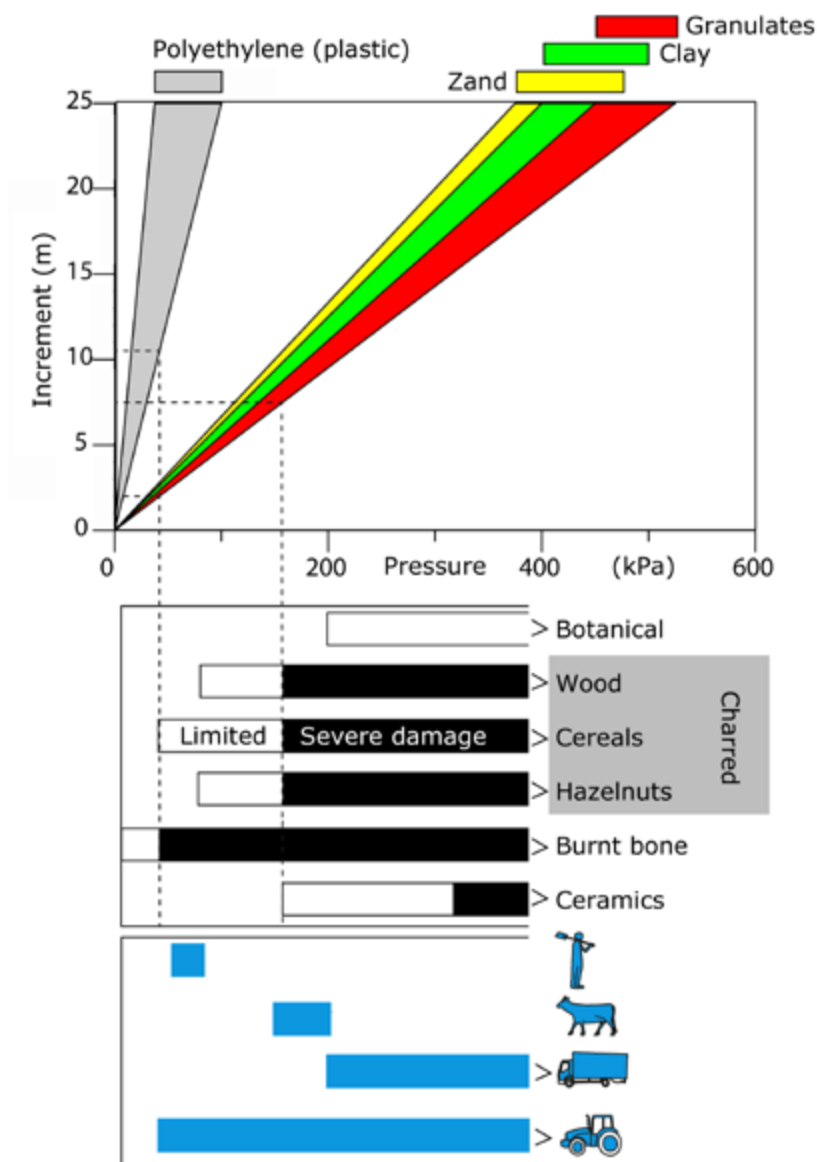


Fig. 5.13 The relation between added soil mass and potential damage to archaeological materials. Top: coloured bands indicate the relation between the volume of deposited soil (in metres) and increased strain, for different archaeological materials. Centre: volume of added soil at which limited (white) or severe (black) damage to small artefacts/ecofacts will occur. Bottom: comparison between, on the one hand, pressure exerted by pedestrians, livestock, and vehicles, and, on the other, that of an added soil mass (image courtesy of Huisman & Ngan-Tillard 2019).

subsoil contains an irregularly shaped non-compacted layer, vertical movements can in turn give rise to lateral movements.

²⁷⁶ Huisman et al. 2011, Section 3.3.4.

²⁷⁷ Schothorst 1967; Locher & De Bakker 1990, 244. Consolidation and compaction are closely related; each is responsible for c. 20 to 30% of the subsidence in peat meadow areas.

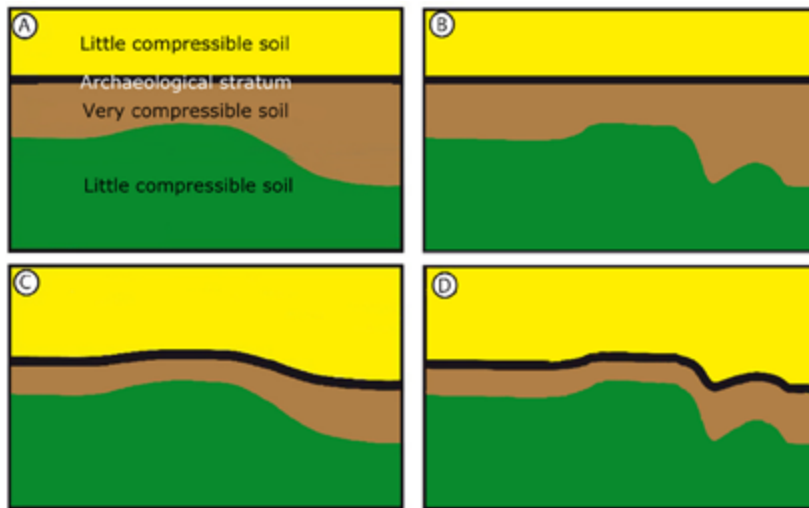


Fig. 5.14 Schematic drawing of the potential effects of strain and compaction on underlying (archaeological) layers and artefacts if a surface is raised with sand. A and B: initial situation. C and D: after 50% of the layer most susceptible to compaction (in brown) has been compressed. The vertical scale is exaggerated (after Huisman *et al.* 2011a).

Different soil types respond differently to a load. Compaction tends to be minimal in sand and mature clay and loam, especially if the soil is 'well settled' (i.e. soil particles are closely packed).²⁷⁸ Soft clay and peat are more susceptible to compaction.²⁷⁹ Compaction is virtually irreversible; once the load is removed soil elasticity will undo only a small fraction of the most recent compaction but most of it is permanent. Soil that has been submitted to a load before will already be compacted, and a subsequent load will therefore have less impact, both in severity and in rate.²⁸⁰ Compaction will reoccur only if the next load exceeds the previous one, until a new equilibrium has been reached. Since water is expelled while consolidation is still in progress, the process can be very slow in soils with limited permeability (clay and peat).²⁸¹ It is widely accepted in soil mechanics that it can take up to thirty years for compaction to reach its final stage. If the added soil load is significant, vertical drainage (see above) may speed up the process.

Although the strain of construction traffic and equipment (e.g. diggers, cranes, dump trucks, lorries) is temporary the effect of axle load should not be underestimated. Because of the small contact surface axle load can many times exceed the pressure of for instance several metres of deposited sand (Fig. 5.13).²⁸² Due its temporary nature the impact of traffic-related strain is limited at greater depth, but at shallow levels, up to c. 50cm, rutting and compaction can cause serious damage (Fig. 6.13).

Sites with compressible archaeological layers, features, objects, or substantial structures are particularly susceptible to compaction (Fig. 5.14). Nonetheless, the damage to smaller archaeological remains by the load of an added soil mass is less than previously thought.²⁸³ Distortion and compression of stratigraphic layers and soil features is a much bigger problem.²⁸⁴ Archaeological objects and their context can be horizontally displaced and larger objects are also more likely to break. The potential effects are all the more serious if a site has a highly detailed stratigraphy. Especially harmful are types of strain which cause an uneven (differential) compaction of the subsurface or horizontal distortion and displacement of archaeological layers (Fig. 5.14). In specific cases the association between an artefact and its soil matrix can be lost, for instance if solid anthropogenic materials are embedded in a soft layer. This applies for example to wooden posts, brick wall remnants, and ship's wrecks, which in the province of Flevoland have been distorted by the superimposed marine clays. In these instances compression of these soft clays can displace the soil matrix that surrounds the remains and even push them upwards into the layer above. Moreover, the retrieval and treatment of botanical remains from compressed material can be a lengthy procedure.

²⁷⁸ Huisman & Ngan-Tillard 2019.

²⁷⁹ Zaadnoordijk & Wonink 1995.

²⁸⁰ Koster & Erkens 2017; Van Laarhoven 2017; Willemse 2017, Section 2.3.

²⁸¹ Roorda & Stöver 2016.

²⁸² Huisman & Ngan-Tillard 2019.

²⁸³ Potvliet 2015, 14; Huisman & Ngan-Tillard 2019; Hans Huisman, Cultural Heritage Agency of the Netherlands, oral communication.

²⁸⁴ Roorda & Stöver 2016, 46.

Shallow foundations²⁸⁵

Shallow foundations are placed directly onto a solid surface rather than on piles/columns or in a foundation trench. The building or other structure may be erected on a relatively large contact surface, such as a slab-on-grade-type foundation (mat or post-tensioned). Only rarely are buildings supported by their walls alone, i.e. without a proper foundation. In these cases the walls rest on a load-bearing surface layer, typically a very stiff, compact clay or sand. This was a common construction method until well into the 20th century.

Whether or not a shallow foundation is technically feasible depends on the planned building mass, the materials that are to be used, and the load-bearing capacity of the soil. Shallow-foundation constructions are susceptible to (temporary) groundwater table fluctuations, which may cause subsidence. In the western Netherlands, where peat and clay soils prevail, shallow foundations can therefore be used only for light constructions. Sandy subsoils are usually suitable. Shallow foundations should be laid above frost level at a minimum depth of 60-80cm -GL. Slab-on-grade foundations can be shallower but only if they are frost protected down to 60cm.

Shallow foundations and surface consolidation (if required) can be particularly disruptive to (very) shallow sites with archaeological remains 80cm or less below the surface, and to archaeological layers that are susceptible to compaction.²⁸⁶ The risk of serious compaction and distortion-related damage decreases if the archaeological remains are situated at a greater depth. Shallow foundations may occasionally be acceptable on shallow sites in a robust (sandy) soil matrix; shallow foundations are less disruptive than foundation piles or trenches, provided they completely avoid the archaeology and any added surface preparation soil mass is light; 50cm usually suffices. Under these conditions the resulting surface strain will not have a negative impact on the archaeological remains. From a perspective of future research, shallow foundations have the additional advantage that they can be removed more easily and without causing new

disruptions, unlike pile or trench foundations. Archaeologists therefore prefer shallow foundations.

Compaction and distortion due to the placement or removal of (sheet) pile foundations.

Heavy-vehicle traffic or operational pile drivers will cause construction-related soil vibrations.²⁸⁷ Vibrations can liquefy saturated soils or compact subsoils. In his 2007 PhD thesis Piet Meijers showed that the average compaction/subsidence of saturated soil near sheet pile walls is c. 10cm.²⁸⁸ However, compactions of 50 to 100cm have also been reported. The effect of sheet piling on the archaeological soil archive is therefore similar to that of columns/piers: disruption as the soil layers are pierced, mixed and distorted.

5.3.5 Water extraction

In the course of a building project it often becomes necessary to temporarily lower the groundwater level so as to keep the construction pit dry. This is achieved by well-point drainage. These changes in groundwater level (groundwater pressure) can be of short duration; once the project is completed the original level is restored. Occasionally, however, a development project involves a permanent change of groundwater and surface water levels; examples are (permanently) lowering the water table in ditches or canals, the excavation of reservoirs, or the installation of drainage infrastructure.

The effects of well-point drainage and allowing the surface to fall dry extend beyond the construction pit; the repercussions of changes in the water table or groundwater pressure can be felt up to several hundred metres away, depending on lithology (clay, sand) and soil composition.²⁸⁹ Changes in soil moisture usually have an immediate impact on the soil oxygen balance and redox situation. The first effect will be the rapid deterioration of non-carbonized organic remains (wood, leather, textile, seeds, pollen) due to desiccation and

²⁸⁵ Dutch: 'op staal'.

²⁸⁶ Roorda & Stöver 2016, 35.

²⁸⁷ www.kivi.nl/afdelingen/geotechniek/geonet/dossiers/trillingen; see also Head & Jardine 1992; Ardito 1994; Meijers 2007.

²⁸⁸ Meijers 2007.

²⁸⁹ Huisman *et al.* 2011a, Section 4.5 From a geotechnical perspective this is an environmental effect.



Fig. 5.15 Application of synthetic resin under foundations (image: product information brochure Uretek, 2019).

fungus activity (Section 5.4.7).²⁹⁰ In non-calcareous soils bone will be equally affected but in calcareous soils it will survive. Further, metals in an oxygen-free zone which is suddenly transformed into an oxygen-rich one will start to oxidize (rust).²⁹¹ How and to what extent these processes negatively affect archaeological remains is still under investigation. One still unanswered question is for instance at what point in time dry conditions will start to have an impact on non-carbonized organic materials.

5-3.6 Covering

Construction activities can affect soil moisture conditions in various ways. The moisture content in exposed soil is regulated by infiltration of precipitation (from above), by seepage and capillary action (from below), and by evaporation and run-off towards surface waters. Because the oxygen content of well-aerated soils (and of precipitation) is usually high while that of seepage water is low, uncovered soils often display banded oxidation colours in the upper section and reduction colours at deeper levels.²⁹² When a surface is covered over, several of these factors change. Under a hard

surface, interaction with the open atmosphere largely ceases and oxygen-rich precipitation runs off, often via drain holes and into sewers or retention basins.²⁹³ Once cut off from the outside atmosphere and trapped under a hard surface, soil moisture will stagnate and if (low concentrations of) organic matter and iron compounds are present can become anaerobic, and reduction-related processes will set in. Furthermore, with rainwater no longer filtering in oxygen-poor groundwater will move upwards due to capillary action, which again results in reduction-related phenomena.²⁹⁴ The main negative effect of reduction-related phenomena beneath a hard surface is that the resulting greyish blue reduction colours blur the contrast between archaeological features and layers and the surrounding soil matrix, thus rendering this potential information source illegible. Blurring of archaeological features occurs in the following circumstances:²⁹⁵

1. Before being covered the archaeological features and/or layers were contained in an aerobic soil environment which became reducing after the cover was applied.
2. The archaeological features and/or layers contain very little non-carbonized organic matter or few finds; otherwise they would still be legible despite 'blue staining' (i.e. under reducing conditions).
3. The process is irreversible, in the sense that colour contrasts will not re-appear once the surface cover or the construction has been removed and aerobic conditions have been restored.²⁹⁶

5-3.7 Stabilization

A soft subsoil can be reinforced by a pressurized combination of two liquids, a synthetic resin and a hardening agent. These two components are injected into the soil, where they react and form a thick, hard, resinous layer (Fig. 5.15).²⁹⁷

²⁹⁰ Van Waijjen 2001b, 28; Brinkkemper 2006.

²⁹¹ For a more detailed discussion of these processes see especially Huisman *et al.* (2009).

²⁹² In the fluvial clays of the Dutch major river valleys, for example, both 'gray-and-blue-staining' (Huisman 2007; Huisman *et al.* 2011a) and 'brown-staining' (Hiddink 2000) have been observed.

²⁹³ See e.g. Wang 2016.

²⁹⁴ Maas 2001.

²⁹⁵ Bertil van Os, Cultural Heritage Agency of the Netherlands, oral communication.

²⁹⁶ Irreversible means that the oxidation colours do not return, or if they do the process will be so slow as to be irrelevant in the context of an archaeological excavation.

²⁹⁷ See e.g. the brochure issued by the Uretek company (www.uretek.nl).

The thickness of the resin layer depends on the soil type and the calculated strain and ranges from a few decimetres to several metres. Some of these synthetic resins expand while the constituent components are reacting, causing enormous expansion stress in the soil which may even lift up building sections.

Injection of (expanding or non-expanding) synthetic resin is used in floor and foundation reparations in residential buildings, or to reinforce or raise for example greenhouse floors and aisles, factory floors, crane rails, or machine foundations.²⁹⁸ In construction (but also occasionally in the context of archaeological excavations) silica gel (water glass) is used if the groundwater pressure needs to be temporarily suppressed in order to prevent flooding and floating structures.²⁹⁹

Because the displacement force of expanding synthetic resins is unevenly distributed its effects on the displaced surrounding soil are also uneven. In theory, the impact on soft soil segments – e.g. peat lenses, soft sandy layers, clays – could be severe, with potentially serious consequences for archaeological remains. No research data on this issue are available. In addition, both synthetic resins and silica gel will form large or small non-permeable slabs in the subsoil which disrupt the moisture balance, while non-expanding resins and silica gel can encase significant sections of the archaeological soil archive, making it inaccessible for future research. To what extent synthetic resins will fill up soil pores – which happens when water glass is injected – is unknown, nor was it possible to trace information on the potential chemical interaction between injected resins and archaeological remains such as organic materials.³⁰⁰



Fig. 5.16 Map of the Netherlands showing urban expansion in the period 1900-2003. Urbanization has been most pronounced in the west and the total urbanized area has grown significantly.

5.4 Changes in the groundwater situation

5.4.1 Introduction

Of the archaeological national monuments in the Netherlands nearly 16% are situated in areas with a relatively high groundwater table (groundwater stage IV or lower, Fig. 3.4, Table 5.5) and contain potentially valuable, non-carbonized organic archaeological remains.³⁰¹ The future preservation of these remains largely depends on groundwater levels and their fluctuations within the area where the monument is situated.³⁰² Since the 1950s the

²⁹⁸ See e.g. www.uretek.nl (consulted 4 December, 2019).

²⁹⁹ For example during the river dune excavation at the site Hardinxveld-Giessendam, De Bruin (Alblasserwaard region), a 1 to 2m-thick layer of water glass was injected to stop water seeping up from below. It was necessary to leave about 10m of soil on top of the silica gel to prevent the water pressure from lifting the entire impermeable layer.

³⁰⁰ Studies do exist on the chemical interaction with soil and water; see for example the product information brochure for Uretek resins.

³⁰¹ Beukers *et al.* 2009.

³⁰² Kostelijk 1986; Asmussen & Moree 1990; Van Heeringen & Theunissen 2006; Huisman 2009; Huisman *et al.* 2011a; De Beer 2019.

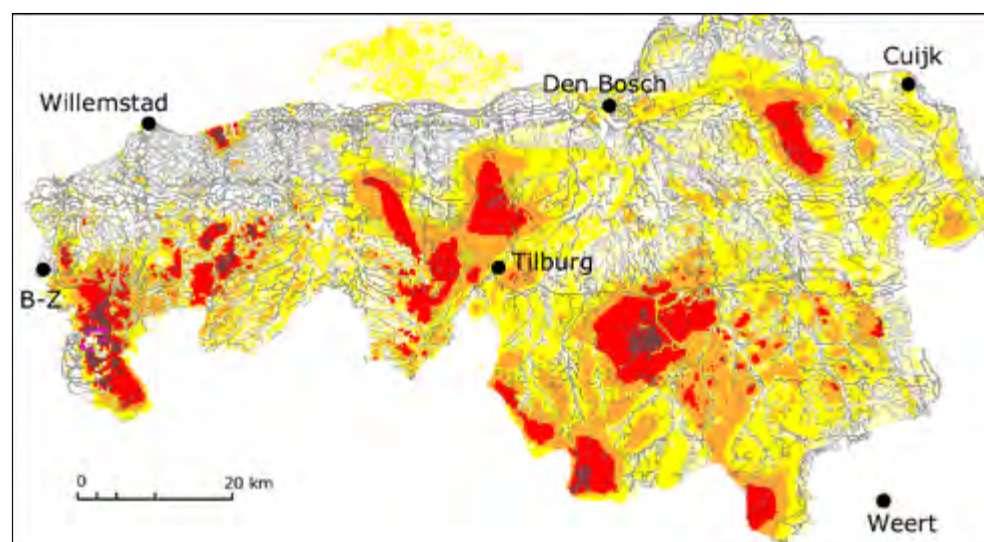


Fig. 5.17 Calculated drop in metres of groundwater levels in the province of Noord-Brabant between 1950 and 2010 due to changes in land use and increased yields (conservative scenario). Dark brown: 2 to 1m decrease; red: 1 to 0.5m decrease; orange: 0.5 to 0.25m decrease; yellow: 0.1 to 0.25m decrease (after Witte *et al.* 2015).

groundwater table in much of the Netherlands has dropped by 20 to 40cm on average.³⁰³

Table 5.5 Groundwater stages at archaeological national monuments.

Groundwater stage	Area (%)
VIII	4,6
VIIo/d	11,3
VII	18,9
VI	1,8
Va	4,4
V	10,7
IV	1,0
IIIa	1,4
III	5,0
II	2,9
I	0,2
W	5,4
Indeterminate	21,5

Table 5.5 Groundwater stages at archaeological national monuments, relative to total area (435,937 ha).

Several factors can alter groundwater levels.³⁰⁴ In the past, large-scale infrastructural projects such as the Afsluitdijk (IJsselmeer Dam) and the creation of the Flevoland polder have had a profound impact on the groundwater

situation. Gehrels *et al.* (1994) estimate that the drainage and reclamation of Zuidelijk Flevoland was responsible for a 1m drop in the water table near the polder's perimeter lake and a 50cm drop at a distance of 14km, towards the former mainland. As early as 1951, Veenenbos reported serious desiccation of the meadows between the towns of Lemmer and Blokzijl in the wake of the 1941 drainage and reclamation of Noordoost Polder.³⁰⁵ Other examples of large infrastructural projects which have affected groundwater levels are the Maas Works and Delta Works, the *Ruimte voor de Rivier* programme ('Room for the River') and its constituent projects (dredging, waterways, nature development), and canal modifications (e.g. Zuid-Willemsvaart).

Another important argument to change a (ground)water table relates to the (desired) water situations in built environments and rural areas.³⁰⁶ In a built environment, a high water table is impractical as it may cause wet crawl spaces and flooded basements. In rural areas especially agriculture benefits from moderate to deep drainage, down to 60cm -GL or deeper. This greatly improves the soil's load-bearing capacity, with less trampling by livestock and less rutting by heavy vehicles as a result.

³⁰³ Wijmer 1990; Van der Gaast & Massop 2005; Werkgroep Achtergrondverlaging NHV 2016.

³⁰⁴ Van der Gaast & Massop 2005; Knotters & Jansen 2005; Werkgroep NHV 2016.

³⁰⁵ Veenenbos 1951.

³⁰⁶ Werkgroep Achtergrondverlaging NHV 2016.

On a much smaller scale, groundwater is continuously being extracted for agricultural sprinkling or for domestic purposes. Extraction for industrial or drink-water purposes mainly affects the hydraulic head of deeper groundwater, resulting in a (potentially) lower groundwater table as well as additional compaction.³⁰⁷

Other factors responsible for the overall trend towards lower groundwater tables are a relative increase in woodland in nature areas,³⁰⁸ and an increase in built environments which replace agricultural land (Fig. 5.16). For example, an increase in woodland and scrub development in nature areas on higher sandy soils has led to more evaporation and less suppletion and therefore lower groundwater tables.³⁰⁹ Precipitation shortages due to climate change also lead to less suppletion of groundwater, a lower groundwater table, and a lower soil moisture content. Groundwater suppletion in urban areas is assumed to be less than in agricultural areas. In urban areas most precipitation flows via drain holes and sewers directly towards surface waters or retention basins, rather than in the soil. Pumping so as to keep the buildings dry is yet another factor in urban areas.³¹⁰ All in all, urban expansion will therefore lead to a lower groundwater table.

5.4.2 Lower groundwater tables due to land management

Since the early 20th century re-allotment and land management projects to facilitate agricultural mechanization and upscaling have been implemented on an enormous scale. In the context of these re-allotment projects the courses of rural roads and ditches were shifted and other field boundaries such as hedges, wooden banks, or lines of trees were cleared, to be replaced by new, larger roads and waterways.³¹¹ Adaptations of the water system mainly consisted of lowering the water table, improving the in- and outflow of water from elsewhere, and pumping up groundwater for sprinkling.³¹²

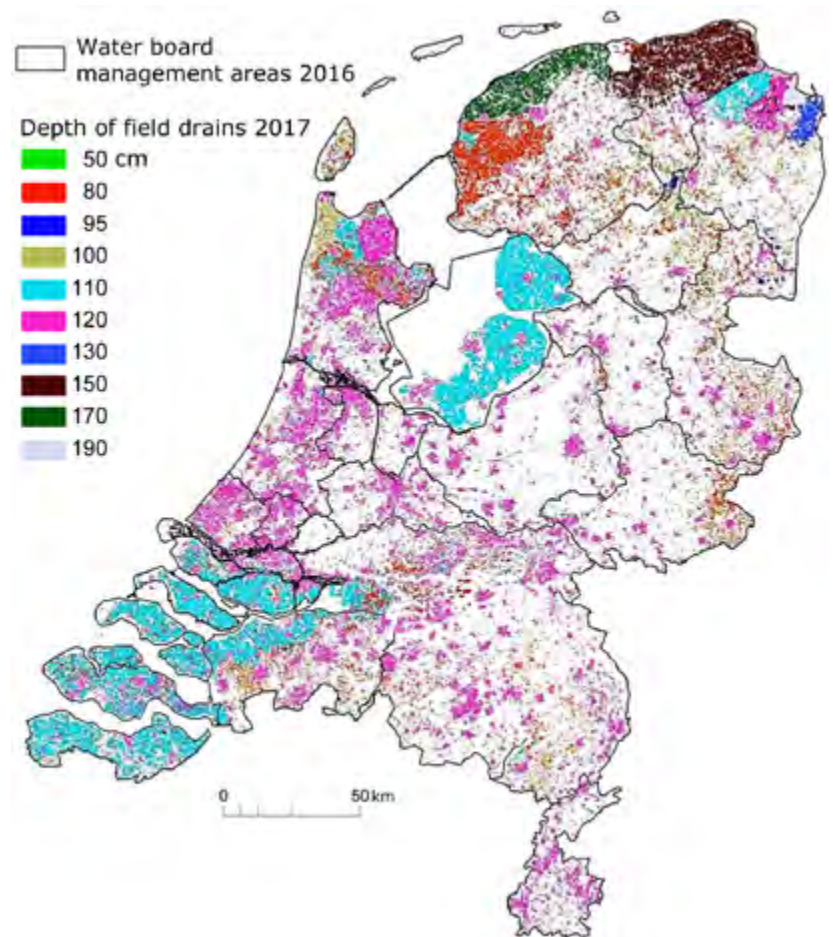


Fig. 5.18 Field drain infrastructure in the Netherlands, 2017 (image courtesy of Massop & Schuiling 2017).

Enlarging (main) water courses and lowering the winter water table were aspects of many re-allotment and land management projects. Other water system improvements involved deepening field boundary ditches (often combined with filling in others to create larger fields) and/or the installation of field drains.³¹³ Between 1950 and 1985 the combined effect of these changes in those parts of the Netherlands that are dominated by free-flow drainage (i.e. which are not polders) has been a significant drop in the groundwater table (Fig. 5.17). Between 1961 and 2004 the average groundwater table in the centre of the province of Drenthe and large parts of the Achterhoek region and the north of the province of Zuid-Limburg has fallen by more than 40 cm.³¹⁴

³⁰⁷ Kremers & Van Geer, 2000; Van der Gaast & Massop 2005; Werkgroep Achtergrondverlaging NHV 2016; Hoogewoud et al. 2016.

³⁰⁸ Witte et al. 2015.

³⁰⁹ Witte et al. 2012; Werkgroep achtergronddaling NHV 2016.

³¹⁰ De Graaf et al. 2013; Jacobs et al. 2015; Werkgroep Achtergrondverlaging NHV 2016.

³¹¹ Koomen, Maas & Weijsschede 2007.

³¹² Rolf 1989; Maas & Von Asmuth 2004; Werkgroep Achtergrondverlaging NHV 2016. Since the extreme drought of 1976 sprinkling has sharply increased, especially on sandy soils in the south and east.

³¹³ Calculations by Van Bakel et al. (2008) show that HGW drops significantly (c. 40 cm) after the installation of a field drain system, with LGW showing a much smaller decrease (c. 10 cm). See also Braat et al. 1989; Werkgroep Achtergrondverlaging NHV 2016.

³¹⁴ Knotters & Jansen 2005.

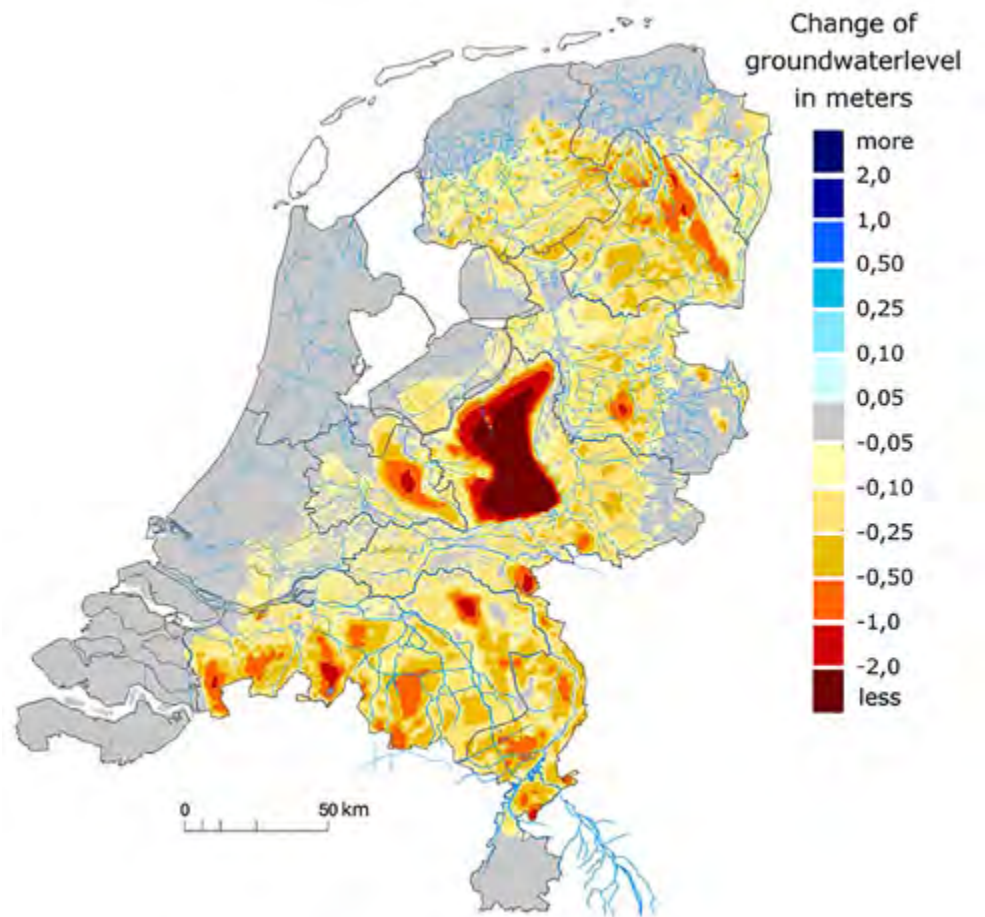


Fig. 5.19 Calculated changes in groundwater level for a scenario involving diffuse water extraction totalling 1,800 million m³ annually (image courtesy of Hoogewoud *et al.* 2016).

In several (land management) sectors, water resource management projects carried out since 1985 resulted in less a pronounced drop in the groundwater table or even in a rise. Overall, however, the original 1950 groundwater stages II and III have mostly become stage VI and to some extent also IV (Table 3.1),³¹⁵ although differences between and inside subsections can be considerable.

5.4.3 Water level ordinances and water level management

Water management in rural areas largely falls within the purview of the Dutch water boards (Du. *waterschappen* or, in some regions, *hoogheemraadschappen*), who implement the water level ordinance in their district. It is up to the water boards to ensure that damage by drought or by excess water is kept to a minimum. Most polders feature a form of active water level management in accordance with the existing land use situation (usually agricultural).

One aspect of water level management is water table indexation. This involves the drafting of a new water level ordinance at regular intervals, usually every ten years, on the basis of the assumption that the agreed upon

³¹⁵ Werkgroep Achtergrondverlaging NHV 2016.

groundwater stages will be maintained.³¹⁶ The manner and timing of the introduction of a new water level ordinance may vary.

In the peat meadow areas of the western and northern Netherlands, the adjustment of nominal polder water levels to lower groundwater tables usually proceeds in stages. After a c. 10cm drop, water boards will adopt a new water level ordinance after which the nominal polder water level is readjusted downwards in 5 to 10cm increments over a period of two years. In other words, in order to maintain the existing polder stage, nominal polder water-level adjustments keep pace with subsidence. After 1950, nominal polder water levels were lowered further to improve the soil load-bearing capacity and facilitate tillage.³¹⁷ Wetterskip (water board) Fryslân summarized this policy as 'level follows function'; 'function' in this context is agricultural use.

Important in this context is the fact that polder groundwater tables have more or less followed the constant adjustment of nominal polder water levels. Over the past few decades this has resulted in a 30 to 50cm drop in groundwater tables, an effect which has extended beyond the polders into the free-draining (non-polder) surrounding areas.

Hydraulic head

Lowering the nominal water level (in polders or elsewhere) also affects the hydraulic head of deeper groundwater because it decreases the pressure (strain) of surface water on the subsoil and the groundwater. Since deep groundwater is under pressure, a decrease in surface water load means that the groundwater will rise to a higher level (in hydrological parlance, a 'higher hydraulic head'). The same phenomenon can be observed when deep construction pits or (archaeological) trenches are excavated, which locally reduces the weight of the soil.³¹⁸ In wetlands (but evidently also in construction pits and installation trenches) a reduced strain due to a lower water table can cause seepage and the rupture of soil layers, and in coastal areas it may lead to salinization (see Section 5.4.8).³¹⁹

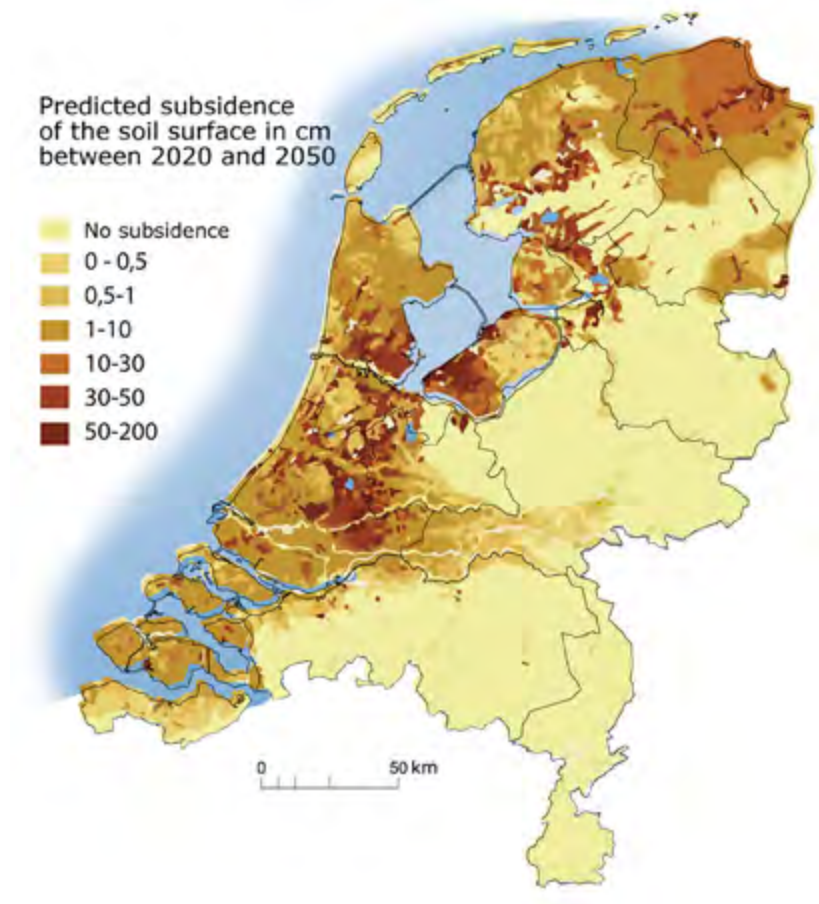


Fig. 5.20 Expected subsidence in the Netherlands in the absence of mitigating measures (after Deltares).

5.4.4 Improving the water situation of agricultural fields

In the past farmland was drained by so-called open drainage systems. Transferring soil dug out of boundary ditches and field margins to the centre of the field, and also ploughing from the edge inwards, created slightly convex raised fields which facilitated the discharge of surface water towards the surrounding canals and ditches. In the northern marine clays (provinces of Friesland and Groningen) this resulted in roughly square raised fields; there could be a 1m difference in elevation between the margins and the centre of a field. On the south-western marine clay areas and along the Dutch great rivers, the resulting fields were long and narrow, and separated by a ditch.³²⁰

³¹⁶ Water level ordinances are issued by water boards for each water level area or sector separately; a water level ordinance has legal status.

³¹⁷ Willemse 2017.

³¹⁸ Reducing some of the pressure from deeper groundwater is often an important argument for well-point drainage, where the goal is not to pump groundwater out of the surrounding layers but to lower the water tension in the water-bearing strata, which has increased due to the reduced soil weight following an excavation. Besides using well-point drainage to reduce the pressure in water-bearing strata an alternative solution is to apply a layer of silica gel under the construction pit.

³¹⁹ Stuyt, Van Bakel & Massop 2011.

³²⁰ Bieleman 2008, 65-66.

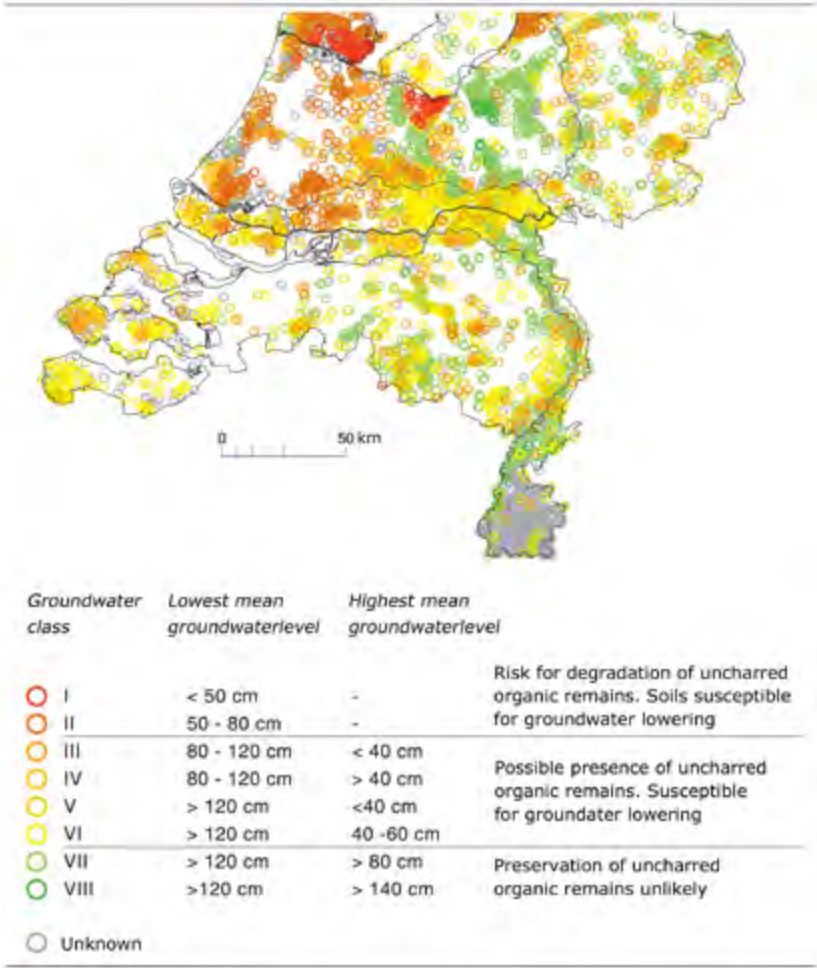


Fig. 5.21 Map of groundwater classes on known archaeological sites in the southern half of the Netherlands. Sites with a significant chance of organic remains being present at shallow depths are marked (after Beukers 2009).

In the late 19th and early 20th century field drainage ditches were starting to be seen as obstacles. Consequently the ditches were replaced by ceramic underground drain pipes, since 1960 replaced by flexible plastic pipes. In the absence of disruptive subsurface layers, the ideal depth for pipe drains is 20cm below the desired spring groundwater table. The minimal depth to avoid damage by frost or axle load is 70cm.³²¹ The transition to a new field drainage infrastructure is still ongoing. Between 2003 and 2010 the amount of agricultural land with field drainage has increased from 14 to 33% of the total – a measure of the scale of this intervention (see Fig. 5.18).³²²

In soils where pipe drainage is ineffective or impossible field drainage furrows are used, sometimes in combination with pipe drains.³²³ These are typically soils with limited permeability, such as alluvial clays or young marine clays, or soils with high groundwater tables, such as fenlands. Drainage furrows are linear depressions or shallow trenches in a field which collect excess precipitation and divert it towards the field ditches. Many field drainage furrows are less than half a metre deep and are not marked on topographical maps, but they are clearly visible on the *Archeologische Hoogtekaart van Nederland* (Archaeological Elevation Map of the Netherlands) and sometimes on aerial photos.

5.4.5 Groundwater extraction

In the last fifty years the average deep-groundwater hydraulic head in the Netherlands (Section 5.4.3) has dropped by more than 30cm.³²⁴ This process started in the mid-1950s and is happening virtually everywhere. The main causes are agricultural practices but above all an increase in groundwater extraction.³²⁵ Around 1950, annual groundwater extraction for drinking water in the Netherlands amounted to c. 250 million m³; around 1998 this volume had more than tripled, to c. 800 million m³ (Fig. 5.19). Groundwater extraction for industrial purposes peaked in the 1970s (c. 500 million m³ per year) but has since returned to 1950 levels (c. 200 million m³ per year).³²⁶

5.4.6 Subsidence in relation to water management

About one quarter of the western and northern Netherlands consists of peat soils. Today 0.4 to 8m thick, their surface has been dropping 0.5 to 2cm each year for centuries. In urban areas, peat soils are subsiding as the load of buildings and raised surfaces compresses the weak subsoil.³²⁷ In rural areas, peat soil subsidence is closely linked to a lowering of the groundwater table for the benefit of agriculture, particularly dairy farming.

³²¹ Ibid.
³²² Massop & Schuiling 2017; Lascaris 2019, 19.
³²³ Massop & Schuiling 2017, Section 3.7.
³²⁴ Kremers & Van Geer 2000.
³²⁵ Werkgroep NHV Achtergrondverlaging 2016.
³²⁶ It should be pointed out again that a clear correlation exists between a lower groundwater table as a result of a lowering of the surface water table, and a lower deep-groundwater hydraulic head which is caused by groundwater extraction.
³²⁷ Born et al. 2016.

The subsidence rate of peat soils varies, but the contribution of water table indexation policies is considerable.³²⁸ Rienks *et al.* (2004) calculated a 0.3 to 0.6m subsidence for peat soils at a 60cm stage in the period 1950–2000. In Polder Mastenbroek (Kampen Municipality), a 40cm drop in the groundwater table was found to lead to an overall subsidence of 20cm within 50 years.³²⁹ For the province of Flevoland, De Lange *et al.* (2012) calculated a 40 to 160cm subsidence due to maturation of the region's marine clay soils. Climate change, particularly warmer and drier summers, will cause a 0.3 to 0.7cm annual increase in the subsidence rate in the western peat meadow areas (Fig. 5.20).³³⁰

Due to variations in soil composition below peat covers subsidence brings about differences in surface elevation. Occasionally this even amounts to an inverted relief, in which ridges that were once completely covered by peat are now visibly emerging on the surface; good examples of this phenomenon can be found in the Krimpenerwaard area, the landscape around Bodegraven and Nieuwkoop, and Zuidelijk Flevoland (Eemstroom area).³³¹ Archaeological remains which were once safe below a protective peat cover (or clay-on-peat deposit) are now within reach of the plough.

5.4.7 The effect of desiccation on national monuments

On soft soils, drainage leads to a 0.5 to 2cm annual subsidence.³³² Since most historical residential and other buildings between the 16th and 20th century have been built directly on this surface and thus subside with it, the water table in many historical towns and cities has already been lowered half a metre.³³³ This is not without certain risks, for some buildings (and infrastructure) have pile foundations. In older buildings these are usually wooden, and if timber piles dry out the foundations they support may be damaged.³³⁴

Another effect of a lower groundwater table and subsequent desiccation is that non-carbonized organic remains (plant remains, wooden objects and structures, textile, leather, ecological remains) will not preserve well once

the surrounding soil becomes aerobic (Fig. 5.21).³³⁵ Anaerobe conditions are crucial for these materials' preservation because this slows down the rate of conversion by soil organisms by a factor 10 to 100.³³⁶ As soon as the groundwater table drops, oxygen can penetrate deeper into the soil and any non-carbonized organic remains that may be present become exposed to degradation and decay by fungi, bacteria and other soil organisms.³³⁷ A case in point is the site Limmen-Heiloo. There, lowering the water table near the site by 0.5m led to an increase in bioturbation. Within six years, 30% more burrows were visible in thin sections, and the quality of pollen and other botanical remains quickly deteriorated.³³⁸

Important contributing factors in this process of desiccation and decay of non-carbonized organic material are soil composition, saturation, and oxygen consumption by soil organisms. Field studies in the Waterland field meadow area (province of Noord-Holland) and at a timber trackway in the peat near Nieuw-Dordrecht (province of Drenthe), an archaeological national monument, showed how even during extremely warm summers some peat soils remain moist (and by extension anaerobe) long enough to slow down biological degradation processes.³³⁹ Another example is a re-allotment project at De Gouw (province of Noord-Holland), where it was observed that the capillary rise of (usually anaerobe) groundwater (Fig. 5.22) in mineral soils can influence saturation levels. When fragile non-carbonized remains are at risk of desiccation, saturation, whether by capillary groundwater or by infiltration of oxygen-rich precipitation, is an important mitigating factor. Water contains little free oxygen (less than 10 mg/l) and what little there is is soon used up by micro-organisms.³⁴⁰ In saturated soils that are rich in non-carbonized organic matter (but also inside e.g. waterlogged wood) this quickly produces anaerobe conditions.³⁴¹

A well-documented example of this effect are the strata inside a terp (and some other artificial mounds, such as mottes), which are often composed of stacked clayey sods and other soil material. When these materials were stacked or covered over, soil organisms started to degrade organic matter such as plant roots, a

³²⁸ Schothorst 1977. Since 2000 the observed rapid subsidence rate and the fact that peat oxidation releases large quantities of greenhouse gasses have led to a greater reluctance regarding adjustments of the nominal polder water level, especially in peat meadow areas.

³²⁹ Schothorst 1967.

³³⁰ Born *et al.* 2016.

³³¹ Terwan, Guldemon & Menkveld 2000.

³³² Van den Akker *et al.* 2007.

³³³ For instance in the city of Gouda (Willemse 2017).

³³⁴ Klaassen 2005.

³³⁵ *Ibid.*; Huisman 2009.

³³⁶ Huisman 2009; Bertil van Os, Cultural Heritage Agency of the Netherlands, written communication. See also Caple & Dungworth 1996; Huisman *et al.* 2008; Historic England 2018.

³³⁷ Van Waijen 2001b; Brinkkemper 2006. Bone also suffers if the soil matrix is poor in calcium but will be preserved in soils with a high calcium content.

³³⁸ Molenaar, Exaltus & Van Waijen 2003.

³³⁹ Oral communication Carla Soonius (West Friesland) en Hans Huisman, Cultural Heritage Agency of the Netherlands; Huisman & Theunissen 2008.

³⁴⁰ Brock & Madigan 1991; Paulissen, Nijboer & Verdonchot 2002, 22, 35.

³⁴¹ Mauro 2001.

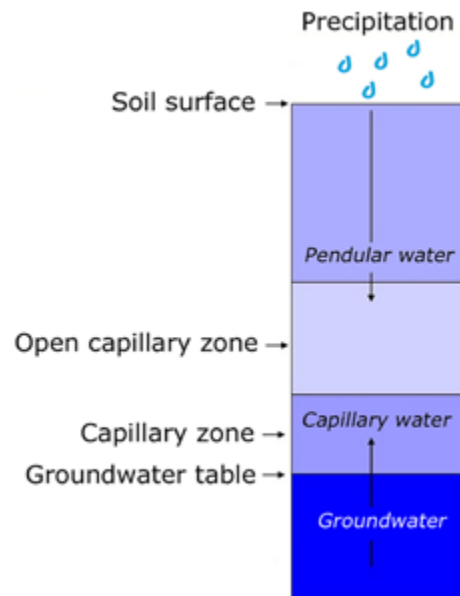


Fig. 5.22 Schematic illustration of the concepts pendular water, groundwater, capillary action, capillary zone, and unsaturated capillary fringe. See the Terms and Definitions for more details.

process which quickly resulted in anaerobic conditions. Terp layers also frequently contain 'waste' that is rich in organic remains and moisture, which upon contact with soil organisms also creates a reducing environment. In combination with for example building rubble that contains mortar, or with bone or shell which contains calcium carbonate, these archaeological layers create their own perfect preservation environment.

³⁴² Willemse 2017.

³⁴³ Vos & Van Heeringen 1997; Brandt, Van der Leeuw & Van Wijngaarden-Bakker 1984.

³⁴⁴ Gerwin & Baumhauer (2000), Kars (1998) and Meeussen *et al.* (1997) studied the effect of lowering the groundwater table and other soil parameters on metal corrosion and deterioration.

³⁴⁵ Werkgroep Pyriet 2002; Huisman 2009.

On peat soils and immature marine clays, consolidation of the upper layers is another effect of agricultural field drainage.³⁴² This phenomenon has been observed in the provinces of Zeeland and Noord-Holland, and especially in Flevoland where subsidence due to field drainage and soil maturation is still ongoing.³⁴³ Archaeological remains at shallow depths, such as wrecks, thus end up in the plough zone. In addition, archaeological remains that are exposed to groundwater fluctuations are susceptible to decay due to changes in their moisture content. This process of repeated desiccation and rehydration of archaeological remains capable of absorbing moisture causes cracking and warping.

Yet another degradation process which is linked to a lower groundwater table is corrosion. Ferrous metals in anaerobic zones which are suddenly exposed to aerobic conditions will start to rust.³⁴⁴ In soils where pyrite (FeS_2) occurs naturally the effects of desiccation and oxygenation are even more pronounced. Pyrite is fairly stable in reducing conditions but reacts with oxygen,³⁴⁵ a process which produces a number of minerals but also sulphuric acid (H_2SO_4). Pyrite containing soils can therefore become strongly acidic when they dry out, which has a negative impact on for example ferrous metals and bone. If such soils are also calcareous (e.g. non-decalcified Rhine deposits or marine deposits) acidification will not occur but gypsum



Fig. 5.23 Restoration of the historical channel of the river Berkel near the village of Almen, province of Gelderland (photo: Waterschap Rijn en IJssel, 2014).

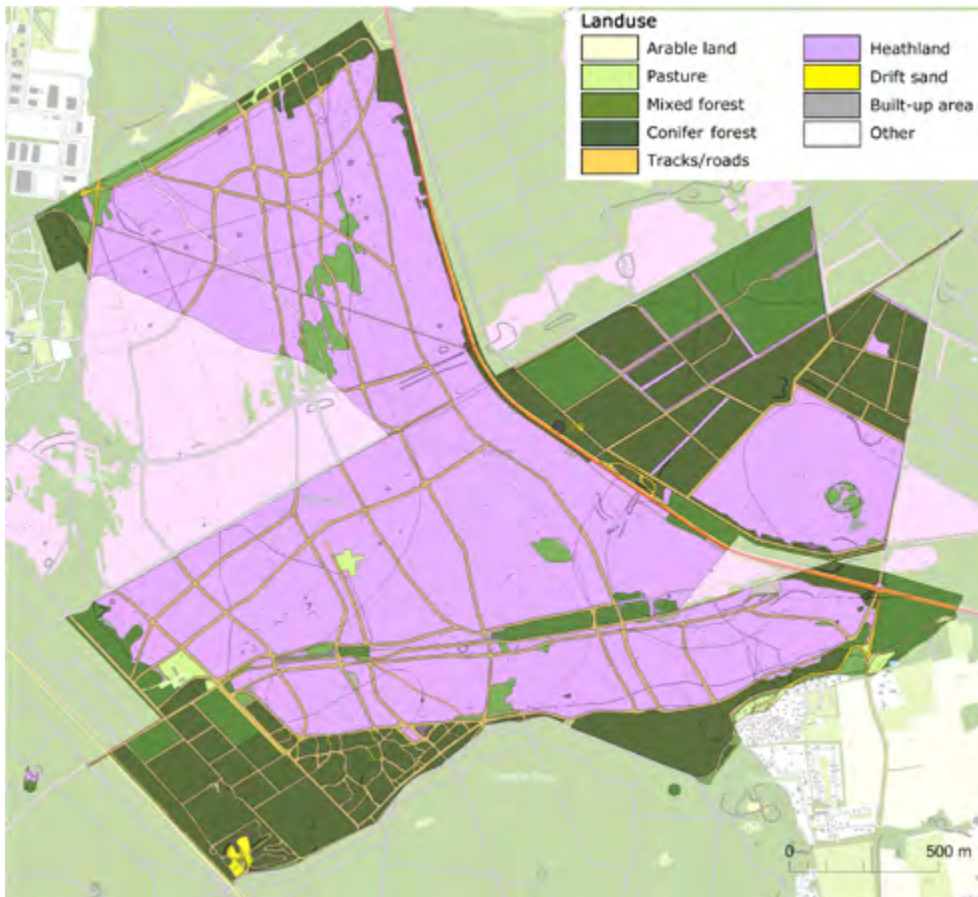


Fig. 5.24 The Roman marching camp at Ermelose Heide (National Monument 45.487).

(CaSO₄) will be formed instead.³⁴⁶ For a more detailed discussion of these processes see Huisman *et al.* (2009).

Secondary effects

At the majority of scheduled sites in the western Netherlands only the deeper archaeological levels are more or less permanently below the water table. However, there is yet another reason why relatively shallow 'wet' sites are particularly sensitive to degradation caused by drainage.³⁴⁷ Due to the greater soil load-bearing capacity which follows upon drainage, areas which in the past were too wet to become anything but (hay) meadows can be converted into arable land, with all that entails for the archaeological remains.

5.4.8 Soil salinization

A widespread problem in the lower parts of the Netherlands, besides desiccation, is excess salt (sodium chloride) in the soil and in groundwater.³⁴⁸ This salt may come from above and below.

Salt influx from below is mainly an issue in coastal areas, where brackish/salt water (i.e. seawater) occurs close to the surface due to salt water seepage and intrusion via river mouths.

In spring and summer, the freshwater layer which formed in winter above the salt water becomes thinner due to evaporation and extraction for field sprinkling, and this reduced pressure enables the salt water to rise closer to the surface. This form of salinization from below can also be caused by the extraction of fresh water for industry and as drinking water (Section 5.4.5).³⁴⁹

³⁴⁶ Gypsum formation can also have a deleterious effect on archaeological remains; see e.g. Huisman *et al.* 2008.

³⁴⁷ Van Heeringen & Theunissen 2001a, 2001b; Van Heeringen & Theunissen 2002; Van Heeringen, Smit & Theunissen 2004; Corfield 2006; Theunissen & Van Heeringen 2006a.

³⁴⁸ Stuyt, Van Brakel & Massop 2011.

³⁴⁹ Hoogewoud *et al.* 2016.

The second type of salinization, from above, occurs in situations where there is an influx of salt into surface water due to diffuse seepage, upward seepage from deep groundwater, or marine influence. When this surface water filters down into the soil or is used for field sprinkling, the soil will become saline.

In theory, soil salinization can have both positive and negative effects on archaeological remains. Salt increases the conductivity of groundwater, thus facilitating the transport of electrons which is an essential component of the corrosion process.³⁵⁰ As such the presence of salt has a negative effect on the preservation of metals such as iron, lead, tin, or silver.³⁵¹ Textiles on the other hand, and especially silk, will be better preserved if the soil salt content is high.³⁵² Whether salinization can cause serious damage to other types of archaeological remains is uncertain.

5.5 Effects of nature and forest management

In forests and nature areas, relatively few human activities have a direct impact on the soil. In the past few decades there has been little encroachment upon these areas, and small raised elements such as earthen banks to stop livestock or game, Celtic fields, and defensive structures are relatively well preserved. The main risk factors in relation to nature and forest management are nature development, turf stripping, and woodland exploitation for timber production.³⁵³

5.5.1 Nature development and management

Nature development

In nature development, areas are managed so as to allow desired ecosystems to develop with a minimum of human interference.³⁵⁴ Areas selected for nature development can be former agricultural land or existing nature areas. The process may involve extensive earth moving activities. An example of the latter is re-meandering, or returning canalized rivers and brooks to their former winding course (Fig. 5.23). Sometimes filled former meanders are re-opened but this is rarely feasible, and often new meanders are dug by heavy machinery in places where none existed before. River re-meandering is often combined with nature development.³⁵⁵

Besides the immediate impact of the excavated new meanders the re-initiated meandering process itself can have a disruptive effect on archaeological remains that may be present. Depending on the width of the river basin relative to the width and depth of the stream channel, between 10% and 45% of the valley bottom may be scoured out by shifting river bends.³⁵⁶ Another major problem is re-allotment in the form of land exchange by farmers whose fields border on the stream, a process which may be accompanied by filling in ditches, levelling, and the installation of a drainage infrastructure. Furthermore, 'stream reconstruction' also affects the water situation in the surrounding fields. In the drainage basin of the small stream Lunterse Beek, for example, Bon (1963) observed that after the water level in the various stream beds was lowered by c. 50 to 60cm the groundwater table dropped 20cm, resulting in the desiccation of the surrounding soils.

In many places 'stream reconstruction' is already a fact (Fig. 5.23); over the next few years another 300km of previously canalized meanders will be reconstructed, a process in which more than 700ha of soil will be turned over.³⁵⁷

³⁵⁰ Scharff 1993.

³⁵¹ Huisman 2009, 134.

³⁵² Huisman 2009, 71 ff.

³⁵³ See e.g. Stobbelaar 2017; Krikhaar 2017.

³⁵⁴ E.g. Lodts *et al.* 2005; Nijssen *et al.* 2011; Loeb *et al.* 2017; Jansen & Grootjans 2019.

³⁵⁵ Verdonchot, Van der Wal & Van Weeren 2011.

³⁵⁶ Lascaris 2019, 34. Regarding the meandering process, see also Candel 2020, 203.

³⁵⁷ *Ibid.*; Lascaris 2019, Section 3.9.



Fig. 5.25 Turf stripping on heathland, Hatertse en Overasseltse Vennen (National Monument 45.864; photo: José Schreurs).

Decreasing the soil phosphate content is another intervention commonly deployed in nature development. On former agricultural land this means removing the cultivation layer (which is saturated with manure), sometimes in combination with ‘soil transplantation’ with soil brought in from elsewhere.³⁵⁸ On Pleistocene sandy soils the result may be a site-wide loss of artefacts and features in the top 10 to 20cm of soil.³⁵⁹ These are the very areas where archaeological remains lie close to the surface (Section 3.5), which renders topsoil removal and ‘soil transplantation’ particularly harmful. More ‘archaeology-friendly’ alternatives which do not involve the removal and/or relocation of soil material, as for example removing phosphate by sowing grass or clover, or applying a potassium fertilizer, are not yet very common.³⁶⁰ Other, smaller nature development projects are the pools with environmentally-friendly edges that are being dug by private landowners, a form of soil removal which is occasionally carried out on a larger scale in the context of nature development projects.³⁶¹

Nature management

Examples of soil interventions carried out in the context of nature management are turf stripping, roller chopping to remove plant litter, deepening/clearing, uprooting trees and shrubs,

pulling wildshoots, and improving acidic soils by means of liming.³⁶² Many heaths in the Netherlands are overgrown by grasses and wildshoots, largely as a result of the airborne deposition of nutrients (‘eutrophication’).³⁶³ To prevent grasses or ruderal species from taking over, here and there eutrophic heathland soils are being degraded by mechanically stripping the turf, scraping the surface or removing the vegetation and top section of the upper humic layer with a roller chopper.

Stripping, scraping or roller-chopping heathland which has turned to grass will also remove some of the subsoil.³⁶⁴ Manual stripping, as in the past, and cutting the sods fairly thinly may seem to pose no threat to archaeological objects, but it is actually more difficult to precisely control the depth with manual cutting than with heavy equipment, which strips the turf to a depth of 15 to 20cm. Van Kimmenaede (1992) lists the following effects and (possible) consequences of turf stripping:

- Archaeological sites with visible surface remains: raised elements and traces are truncated; archaeological remains become exposed to oxidation, bioturbation and erosion, and ultimately disappear.

³⁵⁸ Wubs *et al.* 2016.

³⁵⁹ Smit *et al.* 2007.

³⁶⁰ Timmermans, Eekeren & Bos 2010.

³⁶¹ Jansen & Grootjans 2019.

³⁶² Roller chopping removes the vegetation and some of the humus layer; the technique is suitable for humus layers up to 4cm thick. Roller chopping is done with a heavy-duty flail mower, the flails penetrating a few centimetres into the soil. The chopped material is directly vacuumed up and disposed of.

³⁶³ CBS, PBL, RIVM & WUR 2019.

³⁶⁴ E.g. Loeb *et al.* 2017.



Fig. 5.26 Disturbance by recreational use: an abandoned camper on Herike-Herikerberg, National Monument 45.798 (photo: Datema 2015).

- Sites with a very thin A horizon: artefacts and soil features end up directly on the surface; original artefact distributions and contexts are lost by erosion (displacement), features fade (desiccation, bioturbation), and erode (truncation).
- Heavy rutting on dry and wet soils by machines: particularly sites without (deep) soil features are destroyed; original artefact distributions are disturbed (displacement) and artefacts are crushed (fragmentation).

Scraping and similar activities involve the removal of just the litter with a digger with a smooth-edged bucket. In theory the humus layer is left intact, but in reality a section of the mineral soil is often removed as well. Roller chopping removes both the vegetation and part of the top few centimetres of the humus zone; as such it is an intermediate activity between turf stripping and mowing.

Additional measures are often necessary in the context of nature management, because nature does not always do what we would like it to do. A widespread intervention in open areas where annual mowing is unnecessary is the manual pulling of wildshoots.³⁶⁵ This is common practice especially in areas such as heathland where grazing is part of the management regime, and in composite landscapes of grass, ruderal vegetation, and scrub. Older trees up to 1.7m tall are removed with a brush-cutter or are pulled out by machine, root ball and all. Especially wildshoot pulling (manually or by machine) will disturb shallow soil features.³⁶⁶

Ruderal species and grasses can also be controlled by flailing, in which wildshoots and other plants and roots in the top section of the mineral soil are crushed, mixed, and removed. Flail mowing can also be used. Flail mowing is a form of wholesale mowing which uses chains on a vertically, rather than horizontally, rotating axis. The method is suitable for cutting off wildshoots just above the surface; the soil itself is not touched. Yet another technique is raking: loppings are raked off and moss or dense undergrowth and litter are partly ripped open by means of a tracked vehicle equipped with a detachable steel serrated 'comb'.

As was explained earlier, archaeological sites on scheduled monuments on heathland are often close to the surface, or even visible on the surface. From an archaeological perspective, stripping and scraping are both undesirable interventions while chopping and flailing can be equally damaging. However, the method itself is not the only factor to be considered when assessing its potentially damaging effect. It is equally important to be sure how commissioning bodies and contractors define the terms 'mineral soil' and 'humus layer'. This may vary from person to person; some may use the terms to refer to loose organic matter lying on top of the surface, while others apply them to the upper layers of the original podzol.

³⁶⁵ Weeda, Ozinga & Jagers op Akkerhuis 2006; Jansen & Grootjans 2019.

³⁶⁶ Johnson 1998.



Fig. 5.27 Church with cemetery on top of the terp Hegebeintum/Hogebeintum (National Monument 45.523).

5.5.2 Forest management

One might expect that Dutch forest soils are worked less intensive and on a smaller scale than arable fields, and that archaeological national monuments in woodland environments are less at risk there than elsewhere. Nonetheless, soil interventions do take place in woodland, especially in commercial forestry: clearing trees, dragging or hauling timber, soil preparation (digging, spading, turning), processing (flailing) the loppings, turf stripping, and mowing.

For instance, when a cleared section of forest is being (re-)planted the soil of the clearance is often prepared beforehand. First the litter and c. 5cm of the underlying topsoil are de-turfed in linear strips and turned. This can cause superficial damage to objects that are above the ground. Next, trees are planted manually or by machine, in c. 25cm deep planting holes spaced 1 to 1.5m apart.³⁶⁷ Sometimes a forest trencher is used or a spader to loosen the soil. Obviously this may disturb archaeological features and various types of objects. Moreover, the deployment of heavy equipment such as

harvesters and forwarders causes rutting and soil compaction (Section 6.10).³⁶⁸ In production forests with fast-growing species, mechanized uprooting and replanting are repeated every thirty to forty years, each time accompanied by major soil interventions.³⁶⁹

5.6 Other harmful interventions

5.6.1 Soil removal and quarrying/mining

Typical for soil quarries is their large scale and often also their considerable depth. Surface quarries in particular usually involve substantial areas which are excavated down to several metres. On sandy soils the cultivation layer and any archaeological objects it may contain are dug or pushed away, after which the underlying sand is quarried. Once the quarry is shut down again the cultivation layer is replaced. All that remains are isolated finds without context and with very little archaeological information value left. Raw materials such as gravel and sand are by no means the only reasons for soil removal. Occasionally, soil removal on a large scale is also an element in the creation of recreation

³⁶⁷ Sometimes small tree plugs are used. See e.g. Roos & Neefjes 2006.

³⁶⁸ Lewis 1999; De Vos 2005.

³⁶⁹ Only a small proportion of the Dutch forests are naturally rejuvenating old forests where the soil has not been touched in the past decades (Rövekamp & Maes 2002).



Fig. 5.28 Graffiti on megalith D30, Exloo, National Monument 467.493 (photo: erfgoedfoto.nl/Jos Stöver).

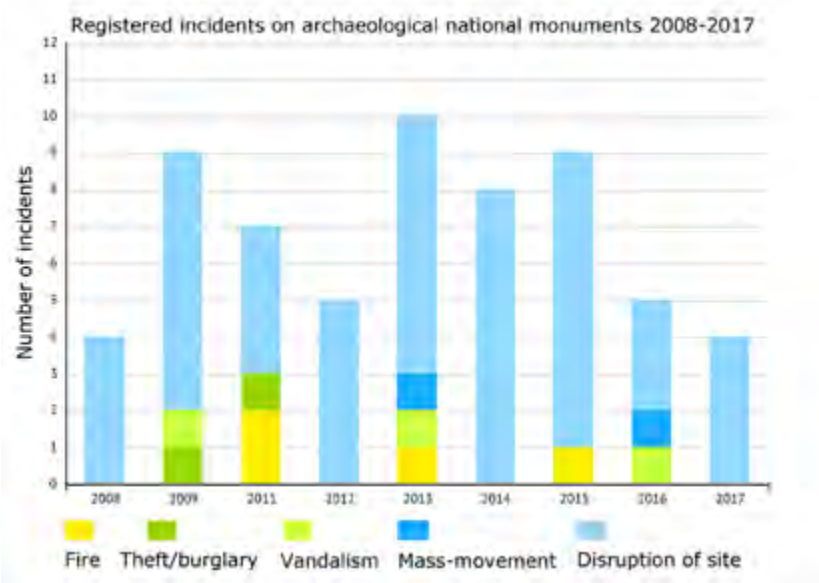


Fig. 5.29 Registered incidents on archaeological national monuments between 2008 and 2017 (image courtesy of Database Incidenten Cultureel Erfgoed/Cultural Heritage Agency of the Netherlands 2018).

grounds, nature development projects, and water retention areas (Section 5.5.1). The *Ontgrondingenwet* (Soil Removal Act) forbids the activity without a prior licence; soil removal inside a scheduled archaeological monument evidently requires a monument permit.³⁷⁰

³⁷⁰ <http://wetten.overheid.nl/BWBR0002505/2016-07-01>.

5.6.2 Recreational pressure

Recreational (co-)use of archaeological national monuments can lead to erosion by pedestrian, equestrian, or bicycle traffic. Sometimes the damage occurs along informal, unauthorized tracks (elephant paths, desired paths) to sections which attract visitors but are inaccessible via official routes. Erosion can also occur at bottlenecks where intense traffic has to pass through a narrow space. Nonetheless most forms of recreational usage by cyclists and pedestrians cause only superficial soil erosion without significant damage to the scheduled monuments themselves, although the soil may become compacted so that water may stagnate on the surface. Slope erosion may intensify because of this and in unfavourable circumstances may cause a pattern of small rills (rill erosion). On bridle paths, rutting and trampling may be a problem.

Sometimes overdue maintenance is the cause of erosion and degradation (Fig. 5.26), or thoughtless action by individuals (e.g. hiking and mountainbike trails across burial mounds or earthen banks; Section 5.6.5).

5.6.3 Heritage management

Inexpert intervention (e.g. uprooting shrubs and stubs by machines) can have a negative impact on a national monument. Opening up archaeological national monuments for the general public often involves the construction of access roads (for pedestrians, cyclists or horses) and parking lots (Section 5.6.2), although these features are nearly always situated in places where they can do no harm, and often in ways that spare the archaeology. Overdue maintenance can exacerbate existing damage to vegetation, embankments, mounds or mottes, and make existing rutting or soil compaction worse.

5.6.4 Funerary activities

In some cemeteries and churchyards inside archaeological national monuments, for instance those on terps, funerals still occasionally take place. Sometimes this damages archaeological remains, for example when graves are dug deeper than in the past or when previously empty sections are used for this purpose.³⁷¹ Furthermore, proposals are sometimes filed for eco-cemeteries on archaeologically valuable sites. In Drenthe, for instance, an eco-cemetery has been laid out in an area which contains seven prehistoric burial mounds and the nearby scheduled megalith of Eext. Another eco-cemetery was taken into use in 2019 on the terp of Wierum near Adorp (province of Groningen, next to the old churchyard and bordering directly on an archaeological national monument (National Monument 45.059).

The development of an eco-cemetery involves grave digging (manually or by machine) as well as the construction of other facilities such as parking lots or signposts. Many cemeteries are maintained by volunteers, whose actions may inadvertently affect or even damage the national monument.

5.6.5 Incidents and vandalism

Occasionally an archaeological national monument falls victim to vandalism (Fig. 5.28) or other forms of what at the very least should be considered thoughtless behaviour, such as lighting a fire inside a megalith, mountain biking across banks and burial mounds, equestrians and pedestrians taking a shortcut and leaving an elephant trail, or motor crossing in arable fields.³⁷²

Unfortunately the fact that some archaeological national monuments are clearly recognizable as such and known to contain a wealth of archaeological objects makes them a clear target for unscrupulous treasure hunters and unsavoury metal detectorists.³⁷³ These activities are strictly forbidden inside

³⁷¹ These are instances of so-called 'current use', which may be continued after the site has been scheduled. This does not apply to churchyards and cemeteries that have been formally decommissioned.

³⁷² See also the publication 'EHBO hunebedden' ('First Aid for Megaliths'; Van der Sanden et al. 2016).

³⁷³ Van Os et al. 2014, 101; Lauwerier & De Kort 2012, 208.

archaeological national monuments and are considered forms of vandalism and theft. In metal detecting and digging for finds by treasure hunters archaeological objects are removed from the archaeological site illegally and without any form of documentation. It impoverishes the archaeological record, and occasionally archaeological features are completely destroyed by illegal digging. A case in point is the Roman fortress (castellum) of Fectio, where it was observed in the course of regular archaeological investigations that the number of copper alloy and silver objects in the upper

archaeological layers was proportionally less than those of lead objects.³⁷⁴ This could mean that copper-alloy objects down to a depth of 30 cm -GL have disappeared, which is suggestive of illegal treasure hunting.

The *Database Incidenten Cultureel Erfgoed* ('Database Incidents [relating to] Cultural Heritage') registered 52 such incidents on or near archaeological national monuments between 2008 and 2017 (Fig. 5.29).³⁷⁵

³⁷⁴ Van Os *et al.* 2014, 101.

³⁷⁵ Cultural Heritage Agency of the Netherlands 2018.

6.1 General

The purpose of physical conservation measures is to ensure the *in situ* preservation of the information value and/or experience value of scheduled archaeological monuments. Together with monument permit policies, physical conservation measures are an important instrument towards long-term soil archive conservation. Two types of physical conservation measures can be distinguished, those that are part of the maintenance regime for scheduled monuments, and those that are an element of site development.

The term maintenance refers to all forms of regular maintenance carried out to keep archaeological monuments in good condition or restore them to such a state, and in the case of visible monuments to ensure that their experience value remains intact. Responsible for this task, in most cases, are the people in the field who regularly carry out activities within the monument's limits, such as farmers, foresters, estate or nature-preserve managers, agricultural contract workers, contractors, builders, supervisors, amateur archaeologists, and nature management volunteers.

Physical site development consists of concrete measures, carried out once or several times when necessary and commissioned by the owner/land user, to prevent or halt further damage to archaeological remains. The purpose of these measures is to safeguard the information value of the archaeological soil archive. Physical site development can take the form of a one-off intervention (e.g. covering a site) but may also involve modifications to a regular maintenance regime (i.e. maintenance model modification).



Fig. 6.1 A consultation, c. 1890, between monument conservation pioneer Victor de Stuers and architect Pierre Cuypers in the ruins of De Haar Castle, Haarzuylens, shortly before the reconstruction of this largest of the Dutch castles began (Built Monument No. 527.893).

6.2 Grounds for protective measures

6.2.1 The level of threat

The necessity and urgency of physical protective measures depend on the vulnerability of the archaeological remains (Section 3.5) but equally on the seriousness of the threat and above all on the risk of information loss (Section 3.4). Other factors concern the measures'



Fig. 6.2 Quarrying on the Menameradiel terp site

expected long-term and short-term effectiveness and their reversibility. The following considerations play a role in an assessment of the level of necessity and urgency.³⁷⁶

1. The nature, scale, and degree of immediate physical threat to the national monument;
2. The risk of serious damage, i.e. a rapid and irreversible loss of information, so that archaeological research questions with regard to the scheduled complex can no longer be answered (Section 3.4);
3. The presence of existing damage, and its ongoing rapid progress.

Dutch heritage organization *Erfgoed Nederland* ('Heritage in the Netherlands'; successor of *Archeologische Monumentenwacht*, 'Archaeological Monument Watchdog') uses a risk classification system based on visible threats. The most recent edition of Protocol *Archeologische Monitor Landbodems* ('Archaeological Dry-land Monitoring Protocol')³⁷⁷ makes use of the same system:

- Limited or no risk: archaeological complexes subjected to extensive forms of land use, such as pasture, heath with extensive grazing, woodland without interventions or recreation, and areas where landowners have shown a great awareness of the vulnerability of archaeological remains;
- Moderate risk: archaeological complexes in areas that are intensively used, such as built-up farmyards, and in nature areas subjected to regular interventions. Other moderate risk factors are increased plant root activity, weakened trees (windfall), and/or increased bioturbation;
- Urgent risk: complexes where new or ongoing disturbance can be expected in the near future, such as grave digging on a cemetery, the formation of cracks in slopes/banks/escarpments, or activity by badgers, foxes or other animals close to the complex.

Regular inspections are essential for an assessment of the severity of the risk to a archaeological national monument. A case in point is the harmful impact of imperceptible processes such as desiccation and moulding due to a lack of groundwater suppletion during dry summers, a gradual process which after a

³⁷⁶ See e.g. Van den Berg *et al.* 2010, 162; Van Os & Kosian 2011; Stewart 2013; Huisman & Van Os 2016.

³⁷⁷ Cultural Heritage Agency of the Netherlands 2019, Version 4.7 (published 6 March, 2019).

specific event (e.g. groundwater extraction for field sprinkling) may nonetheless quickly escalate and become urgent. This was the main argument to set up a system of regular archaeological monument inspections (Section 1.2) to assess and monitor the physical condition of monuments, both those that are visible and those that are below the surface.

6.2.2 Level of urgency

An assessment of the level of physical threat will be supplemented with an evaluation of the urgency of physical protection measures. It is important to distinguish between:

- A direct threat;
- An urgent problem;
- A closed incident.

The difference between a direct threat and an urgent problem is that in the case of a direct threat no serious disturbance need yet have occurred but there is a considerable risk that it may occur if no measures are taken. In an urgent situation some form of serious damage has already occurred and is becoming worse in size and scope, necessitating immediate intervention. In a closed incident the damage is already a fact but there is little or no risk of a reoccurrence or of further deterioration.

Inspection or monitoring of a scheduled monument and assessment of its physical state will result in recommendations for subsequent maintenance or intervention measures. Four levels of urgency are recognized:

1. Low, if no immediate threats have been observed;
2. Moderate, if maintenance so far has been inadequate or overdue but no direct threat has been observed;
3. High, if maintenance so far has been inadequate or non-existent, or in the case of a direct physical threat;
4. Urgent, in the event of a serious disturbance which is becoming worse in size and scope and therefore demands specific protective measures.

6.3 Physical protective measures.

6.3.1 Purpose and considerations

The purpose of physical protective measures is the optimal preservation of subsurface archaeological remains and of an archaeological monument's experience value, and the prevention or mitigation of damage to that monument (as defined in Section 3.4). Ideally, protective measures will be efficient but minimally invasive and practically achievable, and will have been drafted in consultation with the landowner/user. Within the range of possible conservation measures further distinctions can be made depending on the nature of the physical threat in relation to the site's archaeological characteristics, the available manpower and budget, and the views of the landowner/caretaker.

When deciding upon an efficient measure it is important to keep in mind that certain measures can have different and sometimes even opposite effects on different subsurface materials. Application of a buffering agent such as calcium, for example, can improve the preservation of bone or glass but is less desirable in the case of other non-carbonized organic remains, for instance.³⁷⁸ Moreover, the information value of different material categories and archaeological features may vary. In a long-term maintenance plan for a well-preserved Iron Age settlement on the island of Voorne-Putten, where botanical remains have been studied in great detail but the bone material has not, this knowledge gap may be decisive.³⁷⁹ In such a situation it may be advisable to opt for preservation measures which focus on the preservation of bone material.

³⁷⁸ Huisman 2009.

³⁷⁹ Van Heeringen & Theunissen 2002.

Compensation for loss of income

Some protective measures cause a loss of income, for example if arable land is converted into extensively managed pasture, if an area requires redevelopment, or if new equipment needs to be purchased (e.g. an eco-plough). Consultation between the authorities and landowners/users is essential to clarify the wishes of both parties and study possible financial arrangements. In some cases a subsidy in the context of the Uitvoeringsregeling Rechtstreekse Betalingen ('Operational Scheme for Direct Payment'; part of the Gemeenschappelijk Landbouw Beleid, or 'Joint Agricultural Policy') may be an option, in others, a lump-sum payment to compensate for loss of income and/or necessary investments. Purchasing the land and placing it with another land management organization can be another option.

To date no structural solution or budget to compensate for loss of income exists. During large land development projects in the past (e.g. re-allotment programmes) archaeologically valuable areas in use for agricultural production were transferred to a nature management organization. This solution was chosen with regard to a number of burial mounds near Zwaagdijk (province of Noord-Holland). In this instance, however, the primary purpose of the transfer was to protect the area's nature value; the fact that archaeological sites also benefited was a happy coincidence. There have also been a few pilot projects, such as Terpen Fryslân which also had a project budget for compensations.

Effective archaeological monument conservation thus needs sufficient data on the information value and vulnerability of archaeological remains so as to minimize the negative effects of land use and maintenance and to maximize the measures' positive impact. The importance of adequate public information so as to generate the necessary motivation, understanding and also support for conservation policies cannot be emphasized enough. Few monument caretakers, whether they are farmers, builders, or administrators, can be expected to be familiar with the fragile nature of archaeological heritage.

another example is erecting some form of barrier (e.g. a fence) to keep livestock and wild animals away from a site.³⁸⁰

Some incidental site development measures have a more technical and invasive character. Some of the wrecks in the reclaimed polders in the former Zuiderzee have been clamped or covered to create a local biotope with conditions favourable to preservation.³⁸² Elsewhere, in the east of the UNESCO World Heritage Site of Schokland, several former agricultural fields were decommissioned to halt tillage-related forms of damage. In addition a series of water management measures in 2003 at that same former peat marsh island raised the surface water table (and the groundwater table).³⁸³ As a result the area is now much wetter and the processes of peat moulding and clay compaction have slowed down compared to the surrounding (agricultural) fields.³⁸⁴ The intervention has also slowed down the subsidence rate on the former island of Schokland and has had a positive effect on the preservation of its archaeological remains.

6.3.2 Types of conservation

Physical conservation measures can be simple and maintenance-related (limited impact on the landscape, low cost, limited impact on current land use) or take the form of incidental site development measures involving large-scale, technical interventions and professional expertise.

An example of practical maintenance is regular mowing and the removal of wildshoots on and near burial mounds. Immediate repair of small defects to a bank or mound to prevent erosion and further deterioration is an example of a more limited single intervention.³⁸⁰ Yet

These are only a few examples of physical conservation measures to keep archaeological national monuments in good condition and remove potential threats. The following list of (often self-explanatory) physical conservation measures is based on the available international literature. These measures can be applied singly

³⁸⁰ Baas & Raap 2006/2010, Chapter 3: *Cultuurhistorische beheermodellen*. See also Boosten & Penninkhof 2019.

³⁸¹ Dunwell & Trout 1999; English Heritage 2000.

³⁸² E.g. Speleers et al. 2016.

³⁸³ Smit et al. 2005.

³⁸⁴ See the report 'De fysieke staat van het Werelderfgoed Schokland en omgeving in Nederland' ('The Physical State of the World heritage Site Schokland and Surroundings in the Netherlands'; Cultural Heritage Agency of the Netherlands and Noordoostpolder Municipality, in prep.).

or in combination.³⁸⁵ They can be subdivided into preventive and mitigating measures; the latter aim to undo (some of) the damage and mitigate its causes.

Prevention

1. Modified agricultural use, for example by shifting to less disruptive forms of tillage or by converting archaeologically sensitive field sections to grassland;
2. Modified forest and nature management, such as using fixed thinning tracks through the forest, and measures to prevent rutting and compaction;
3. Modified water management, such as taking hydrological measures to improve the groundwater situation and counteract moulding processes;
4. Using archaeology-friendly construction methods on archaeological national monuments;
5. Preventing damage during installation and construction activities;
6. Covering and/or clamping archaeological sites, for example when the site is at risk from agricultural use, animal activities, or vandalism (e.g. treasure hunting);
7. Modified use of vehicles and machines so as to prevent rutting and soil compaction.

Reparation and control

8. Modification of cultivation practices/agro-nomic management to prevent (invisible) erosion;
9. Vegetation control, such as removing trees to prevent root action and windfall, or applying root cloth or other root barriers;
10. Preventing damage by wild animals or livestock by covering the site with wire mesh, enclosing sections of the area, or erecting a permanent barrier;
11. Managing recreational use, for instance by controlling visitor flow, or by anti-vandalism measures.

6.4 Modified agricultural use

Among the main threats to the preservation of archaeological national monuments are intensive forms of agriculture.³⁸⁶ This is why neighbouring countries have introduced alternative methods to reduce the pressure on the soil archive, as part of archaeology-friendly forms of maintenance.³⁸⁷ These alternatives range from completely abandoning all forms of tillage (no-till farming), switching to so-called direct-sowing methods or creating a local tillage-free zone around archaeologically sensitive sections of the site (e.g. visible archaeological structures), to switching to so-called minimum tillage.³⁸⁸ Other options are raising the site or applying a soil cover, and avoiding (other forms of) soil intervention by fencing the site in or allowing it to lie fallow.

6.4.1 Direct sowing and minimum tillage

In techniques like non-reversal tillage, non-ploughing, or direct sowing the catch-crop residue (green manuring) or the waste of the last harvest are mostly left behind on the surface. Direct sowing is the least invasive cultivation technique suitable to arable farming.³⁸⁹ Direct sowing is a non-tillage technique in which the main crop is sown directly into the catch-crop or harvest residue by a special-purpose sowing machine, without soil preparation.³⁹⁰ However, herbicides are necessary to control weeds and to remove the stubble. Direct sowing is suitable for crops like grasses, cereals, peas and beans, but its success depends on soil type.³⁹¹ The method has the disadvantage that compaction can still occur so that decompaction will be necessary to prevent the crop from being affected by excess water (Section 5.2.4).

³⁸⁵ Baas & Raap 2006/2010; Roorda & Stöver 2016; Boosten & Penninkhof 2019. Examples of physical measures in other countries are listed in Thorne 1988; Shockley 2000; Crow & Moffat 2005; Rimmington 2004; Jones 2007; Stewart 2013; Aslan *et al.* 2018; Historic England 2016; Tjelliden *et al.* 2016.

³⁸⁶ Trow, Holyoak & Byrnes 2010.

³⁸⁷ Germany: Kretschmer & Möndel 2015; Deutsche Bundesstiftung Umwelt 2011, 65 ff.; England: Russell 2003; Booth & Spandl 2009; Holyoak 2010; Belgium: Louwagie *et al.* 2005. See also ITADA 2006.

³⁸⁸ Mauro 2001; Oxford Archaeology 2002; English Heritage 2004; Terwan & Ringers 2004; ITADA 2006; Oxford Archaeology 2010, 11 ff.; Landesdenkmalpflege Baden-Württemberg 2013; Kretschmer & Möndel 2015.

³⁸⁹ Oxford Archaeology 2002, 12; 2010; Kretschmer & Möndel 2015.

³⁹⁰ Gillijns *et al.* 2005: 32; Landesdenkmalpflege Baden-Württemberg 2013; www.pfluglos.de.

³⁹¹ Oxford Archaeology 2002, 12.

Mauro (2001) mentions eco-ploughing as an example of minimum tillage. The goal of minimum tillage is keeping soil organisms in the upper layers and drawing more benefit from available nutrients.³⁹² The technique uses a specially developed plough capable of turning the soil to a depth of 15 to 20cm. This is much less than the depth of the average plough soil; soil compression by the shear is also less.³⁹³ Drawbacks of minimum tillage are the fact that weed control is more difficult and that crop residue is not ploughed under. Minimum tillage also requires different equipment as well as adjustments to other farming aspects, such as scheduling.

Research outside the Netherlands has demonstrated that at least on soils sensitive to slaking and/or drying, limiting tillage to seedbed preparation does not result in smaller cereal yields.³⁹⁴ Few data are available on the technical possibilities and economic feasibility of minimum tillage in the Netherlands.³⁹⁵ Many Dutch publications have addressed the subject under the heading 'non-reversal tillage'.³⁹⁶ Non-reversal tillage uses three basic principles: minimum tillage, maximum soil cover, and maximum crop rotation. Several forms of non-reversal tillage exist depending on the affected depth (deep or shallow), but all avoid a deep soil reversal or mixing. The most radical variety is the above mentioned no-till method, which dispenses with ploughing altogether (Fig. 6.3).

6.4.2 Raising or sanding the surface

An alternative solution is raising the field so that archaeological remains are longer affected by ploughing. Raising grassland prior to its conversion to arable was the preferred option at the Tjessens scheduled archaeological monument at Waaxens (Noardeast-Fryslân Municipality). After consultations with the local Council and with the Cultural Heritage Agency of the Netherlands the current land user applied a

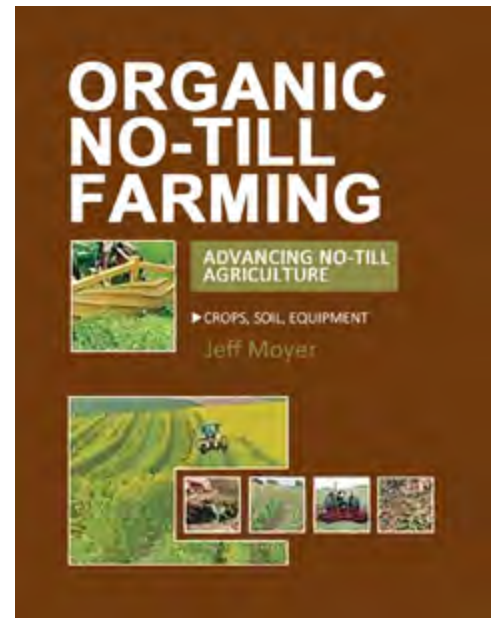


Fig. 6.3 No-till farming (illustration: Jeff Moyer).

30cm layer of soil to ensure that his plough would no longer impact the archaeological remains. The project has been monitored since then, and so far the results have been encouraging.³⁹⁷ A similar form of site development was one of several possible scenarios for the physical protection of the scheduled archaeological monument Aartswoud-De Hooge Weere.³⁹⁸ One of the conditions in this case was that loss of income as a result of raising the surface should be avoided. Also important, from an archaeological perspective, was the need to avoid introducing archaeological remains foreign to the site together with the imported soil. Finally, compaction as a result of the applied soil cover was to be avoided.

A somewhat similar measure is sanding. In sanding a thin layer of sand is applied to the surface to improve its load-bearing capacity and lessen the impact of machine traffic on soil compaction;³⁹⁹ in the past the technique was used on peat soils.

³⁹² Ibid.; Kouwenhoven *et al.* 2002;

Hanegraaf & De Visser 2003.

³⁹³ Oxford Archaeology 2002, 22. Clearly this is dependent upon the type of agricultural equipment and on soil type.

³⁹⁴ In its chapter on tillage, the classical Dutch publication *Handboek Bodemkunde van Nederland* ('Manual of Pedology in the Netherlands') states that deeper forms of tillage do not necessarily result in higher yields (Schneider & Huinink 1990; Chapter 12 in: Locher & De Bakker 1990).

³⁹⁵ However, see also Kouwenhoven *et al.* 2002; Pulleman *et al.* 2003.

³⁹⁶ See e.g. Van der Horst 2015.

³⁹⁷ See Van der Heiden, Van Doesburg & Stöver 2017, and the article 'De ploegproef' in the Cultural Heritage Agency of the Netherlands' own magazine, Vol. 1-2020.

³⁹⁸ Van Eerden 2004.

³⁹⁹ Heunks 1995, 21.

6.4.3 Laying fallow and enclosure

A measure that can be taken immediately once it has been established that a scheduled monument has been damaged (for example when fresh archaeological material is being ploughed up) is laying the field fallow. To reduce the risk of inadvertent ploughing or other forms of tillage on a sensitive part of a field, that specific section can be enclosed, with a wide margin (Fig. 6.4) as a buffer zone around the sensitive part of the monument. The enclosed area will remain fallow, but in situations susceptible to erosion (e.g. on slopes, or on soils that are prone to drifting; Section 6.11) this may actually be counter-productive.

A reduction in the cultivated surface represents economic loss. However, in 2019 fallow fields sown with nectar plants (nectar and/or pollen) were included in the *'lijst van toegestane invulling van ecologische aandachtsgebieden'* ('List of Approved Forms of Utilization of Ecological Attention Areas') and as such became eligible for subsidies under the *Subsidiestelsel Natuur en Landschap* (SNL; 'Subsidy Scheme Nature and Landscape'). A compensation scheme can also be helpful in the implementation of this particular conservation measure. If laying fallow is the preferred option, it is important to see to it that shrubs and seedlings do not invade the enclosed area (Section 4.2.4) as this would attract rabbits and other burrowing animals (Section 4.2.3).

6.4.4 Grassland management, conversion to grassland

Most archaeology professionals point to grassland or pasture management as the most suitable type of land use from a perspective of archaeological monument conservation (Fig. 6.4).⁴⁰⁰ Advantages that are often mentioned are a reduced risk of soil erosion, the positive effect on soil humidity, and the reduced need for breaking or ploughing the soil. An additional advantage is the fact that the risk of physical damage to subsurface remains and features is also reduced because there is less need to deploy heavy and/or invasive equipment.⁴⁰¹ These last two effects (less intensive tillage, less heavy-vehicle traffic) apply also, albeit to a lesser degree, to production grassland or grass cultivation, both of which involve frequent breaking or ploughing, injecting manure, and year-round repeated mowing, all with heavy equipment.⁴⁰² Even on production grassland, however, the plough soil is thinner than on arable fields, and many forms of tillage involve a shallower depth on grassland than on arable.



Fig. 6.4 The motte 't Hof Blaemskinderen, 's-Heer Abtskerke (National Monument 45.203), set aside in an arable field. A solitary linden tree marks the motte's summit. Ploughing has caused some slight damage at the foot of the slope (photo: Aerophoto Eelde).

⁴⁰⁰ Darvill & Fulton 1998; Oxford Archaeology 2002, 2010; Molenaar *et al.* 2003, 50; Van Eerden 2004, 19-20, 25; English Heritage 2004; Rimmington 2004; Terwan & Ringers 2004; Baas & Raap 2006/2010.

⁴⁰¹ Oxford Archaeology 2010.

⁴⁰² Hanegraaf & De Visser 2003, 58.



Fig. 6.5 Timber harvest in a forest (photo: Oldebolhaar B.V.).

The frequently voiced concern whether conversion from arable to grass actually constitutes an effective protective measure from an archaeological point of view is justified. After all, is it not very likely that years of ploughing have already damaged the monument? This argument can be countered by pointing out that the current trend towards more powerful and deeper ploughing with increasingly heavier equipment is exacerbating the risk of progressive truncation and compaction of archaeological levels below the arable layer. Without protective measures the deterioration will become progressively worse. Moreover, shallow and deep levelling have become more common in arable farming. On the other hand, a grassland maintenance regime may indeed quickly merge into regular grassland exploitation (involving regular shallow breaking up of the soil, regular manuring, and frequent heavy traffic) in order to keep the grass yield constant. Opting for this form of land use therefore needs to be conditional upon fulfilment of explicit recommendations as to how the grassland is to be managed from a perspective of archaeological monument conservation.

For archaeological scheduled monuments in rural areas a function as extensively managed grassland is preferable, provided optimization from an economic perspective (which would involve ploughing, manuring, and/or levelling) is not a goal. Furthermore, in the case of shallow

archaeological remains composed of materials sensitive to aerobic processes it is recommended that the selected form of grassland management can tolerate a relatively high groundwater table throughout the year. It is important that existing ditches or other forms of local drainage remain unchanged. In areas with a high groundwater table nothing should be changed in this regard, and the nominal water table should also be kept the same. Grazing on extensively managed grassland is another key factor in the long-term conservation of archaeological sites, because grazed fields require less frequent machine mowing.⁴⁰³

6.5 Adjustments to forest and nature management

A 2015 random sample survey demonstrated the great importance of regular inspections of and maintenance on archaeological national monuments in woodland and heathland settings, as such monuments tend to be overlooked by the landowner, who is more likely to concentrate on production forest or nature management.⁴⁰⁴ A function as 'woodland' or 'nature' also risks damage due to recreational activities or animal activities. Forestry in particular can have a

⁴⁰³ English Heritage 2004.

⁴⁰⁴ Datema 2015, 19. Maintenance mostly takes the form of keeping the surface of mounds and a few mottes in good condition and carrying out repairs.

negative impact on archaeological remains (see Section 5.5). Fortunately the negative side-effects of timber production on shallow archaeological remains can be contained by relatively minor adjustments to the standard methods.⁴⁰⁵ All forestry work on archaeological national monuments should keep sufficient distance from vulnerable sections, so as to avoid possible damage. It is therefore important that vulnerable sections are recognizable as such. Closing off embankments or mounds with barricade tape, or using other means to fence off or mark scheduled monuments are all practical methods. In woodland areas, wood chips or loppings can be used as matting to prevent rutting and compaction by forestry equipment and tractors;⁴⁰⁶ these materials are cheap, renewable, and biodegradable, and easily available in a forest setting. Traffic on wet soils should be avoided to prevent slaking and rutting. Potvliet (2015) and Jansen *et al.* (2018) propose the following measures to prevent rutting and soil compaction:⁴⁰⁷

- The construction and use of preferably fixed thinning and dragging tracks;⁴⁰⁸
- Placing matting on the thinning and dragging tracks;
- Harvesting timber in damp conditions on sandy soils, and in dry conditions on loam and clay soils;
- Using machines with a limited axle load (or draught animals) to minimize rutting (Section 6.10);
- Using uniform tree markings to indicate thinning and dragging tracks (this will be helpful to managers and contractors);
- Recording the precise location of thinning and dragging tracks for the benefit of future forestry cycles by means of GPS and/or map coordinates. Since it is more efficient ecologically and economically to use the same tracks for generations, it makes sense to record these tracks by means of coordinates so they can be reused after clear-cutting.

When planting trees it is recommended to plant each tree individually, for instance with a spade or a planting auger.⁴⁰⁹ If trees are felled it is important not to uproot them. Tree trunks can be left to rot *in situ*. When trees are cut the crowns should not be allowed to land on top of an archaeological site (such as a mound), because the enormous force of the fall can do considerable damage. If this cannot be prevented, the site should be adequately covered. It is recommended to start with trees around and outside the perimeter of the site, so that those inside the perimeter will have room to fall outwards, away from the site.

6.6 Adjustments to water management

6.6.1 Waterlogging and preservation

Preventing desiccation and aerobic degradation processes is key to the preservation of non-carbonized organic archaeological remains.⁴¹⁰ Important in this regard are the groundwater situation and in particular the presence of stagnant groundwater around archaeological remains.⁴¹¹ These preservation conditions depend on the depth of the archaeological remains relative to the groundwater table, on how and to what extent groundwater will permeate and remain trapped in shallower soil strata through capillary action (Fig. 5.22), and on the relation between the groundwater table, nominal polder water table, and the presence (or absence) of a drainage system. A high nominal polder water table need not always be associated with a high groundwater table or with high levels of soil humidity. During periods of excess precipitation (October–March) many areas display a convex (higher) groundwater table (relative to the nominal polder water table) with an apex towards the area's centre. During a precipitation shortage (April–September) this will change into a convex (lower) groundwater table.⁴¹²

The examples in Section 5.4.7 showed that measures to counter the effects of desiccation should be based on a thorough understanding of the local hydrological and hydro-chemical situation. Experience gained over the last few

⁴⁰⁵ For the UK, see Jones *et al.* 2002: 49; Crow & Moffat 2004; Forestry Commission 2017; for Germany, see Sippel & Stiehl 2005; for the Netherlands, see Bosschap 2010; Potvliet 2015; Jansen *et al.* 2018; Boosten & Penninkhof 2019.

⁴⁰⁶ Potvliet 2015, 44.

⁴⁰⁷ See also Boosten & Penninkhof 2019, 78.

⁴⁰⁸ There is a growing tendency in forest management to use fixed dragging tracks spaced 20 to 40m apart, whereby heavy vehicles are confined to those tracks and are barred from using the forest sections in-between. When marking fixed dragging tracks on scheduled archaeological monuments it is important to take into account the more vulnerable sections.

⁴⁰⁹ Boosten & Penninkhof 2019, 77.

⁴¹⁰ Van Heeringen & Theunissen 2002; Huisman *et al.* 2008; 2009; Huisman & Mauro 2013.

⁴¹¹ E.g. Exaltus & Soonius 1997; Van Waijen 2001a and b; Behm 2000; Van Eerden 2004.

⁴¹² Kostelijk 1986; Locher & De Bakker 1990, Chapters 9, 10 and 11.

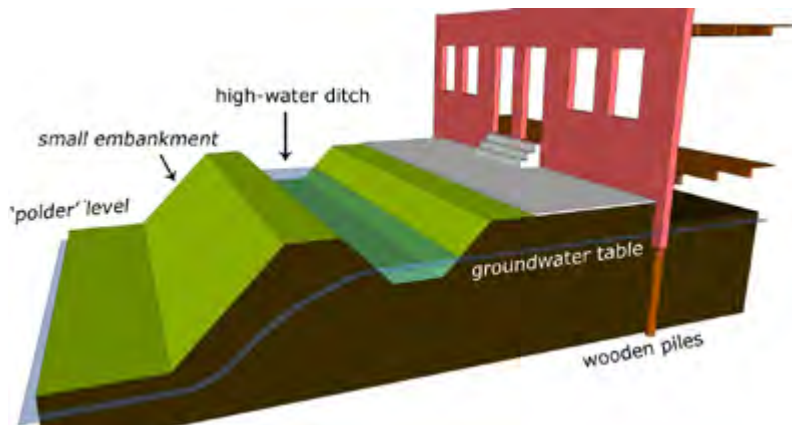


Fig. 6.6 The function of a so-called 'high-water ditch' (illustration: Kenniscentrum Aanpak Funderingsproblematiek).



Fig. 6.7 Information panel at Schokland, National Monument 46.033 (photo: Smit *et al.* 2015).

years has indicated that minor changes in the groundwater situation or in soil humidity in the capillary fringe can considerably improve *in situ* conservation. Nonetheless there are occasions when only radical intervention can remedy the situation.⁴¹³

⁴¹³ Exaltus & Soonius 1997; Van Heeringen, Smit & Theunissen 2002; Van Heeringen & Theunissen 2005; Smit, Mol & Van Heeringen 2005; Huisman & Mauro 2013.

⁴¹⁴ Van den Akker *et al.* 2010.

6.6.2 Maintaining an adequate (ground) water level

Where archaeological levels containing non-carbonized organic remains exist at shallow depth, it is recommended to first take measures to counteract any fall in (ground)water level. A farmer/landowner can do this only in situations where the local water table is artificially kept below that of the surrounding area. Changes to the nominal (polder) water level are the responsibility of the local water board. Furthermore, it should be realized that even if the nominal water table is high (30-40cm -GL) the groundwater table in the area concerned can still drop to 60 to 80cm -GL during a dry period (a so-called concave or 'hollow' groundwater level.) Raising it is only moderately effective.

Technical solutions such as underwater drainage appear to slow down the phenomenon of convex/concave groundwater levels on peat soils during wet and dry seasons respectively.⁴¹⁴ In this form of drainage, drainage pipes are placed 20cm below the nominal water table and 60cm below the surface. In summer, this allows water to infiltrate from the surrounding canals into the drying field, thus hopefully reducing the 'concave' effect and limit peat degradation and consolidation. In winter, drainage will flatten a convex groundwater level. The technique reduces the sometimes extreme water level fluctuations in peat soils or ends them altogether. However, the method is only effective if soil permeability is sufficient to allow the dampening effect to occur.

Installing a drainage system disrupts the soil and its archaeological remains (Section 5.2.6), raising the question whether this is an acceptable physical measure to prevent desiccation of archaeological remains. Moreover, underwater drainage is a relatively new technique which has not yet been tested on scheduled monuments.

6.6.3 Raising the water level

In many cases raising the nominal polder water level will improve the preservation of archaeological remains that are vulnerable to desiccation. A higher water level means that those remains are cut off from oxygen so that natural degradation processes are slowed down or even completely brought to a halt. However, the measure will also affect a number of non-scheduled plots, and landowners may object to this. Raising the nominal polder water level is therefore not a feasible solution.

Raising only the local nominal water level, for instance by constructing a (small-scale) infrastructure around the site that will artificially create a higher level (inundation screens, small sluices, retention dams), is a useful conservation measure only to the extent it actually improves the conditions for preservation (Fig. 6.6).⁴¹⁵ Uncertain factors in this respect are the subsurface depth of fragile archaeological remains but also, again, the sometimes weak (and variable) correlation between nominal water level and groundwater level. Then there are practical considerations. If for instance agricultural usage is to continue, the groundwater table cannot exceed c. 30-40cm -GL. The same practical obstacles exist if the groundwater level maintained by means of local, privately controlled field drainage is below that of the polder level of the surrounding areas.

One method to achieve a higher nominal local level is by constructing culverts.⁴¹⁶ An example of a large-scale approach is a series of hydrological interventions at Schokland in 2003 to raise the monument's freatic groundwater level (Fig. 6.7).⁴¹⁷ One of the reasons for the intervention was to improve the preservation of the archaeological sites. Monitoring data collected since 2000 clearly indicate that preservation conditions for organic remains at the site P14 as well as in a large section of the rest of the hydrological zone – especially the north – have indeed improved.⁴¹⁸

On the other hand, raising the water level may also be inadvertently and indirectly responsible for a gradual deterioration of

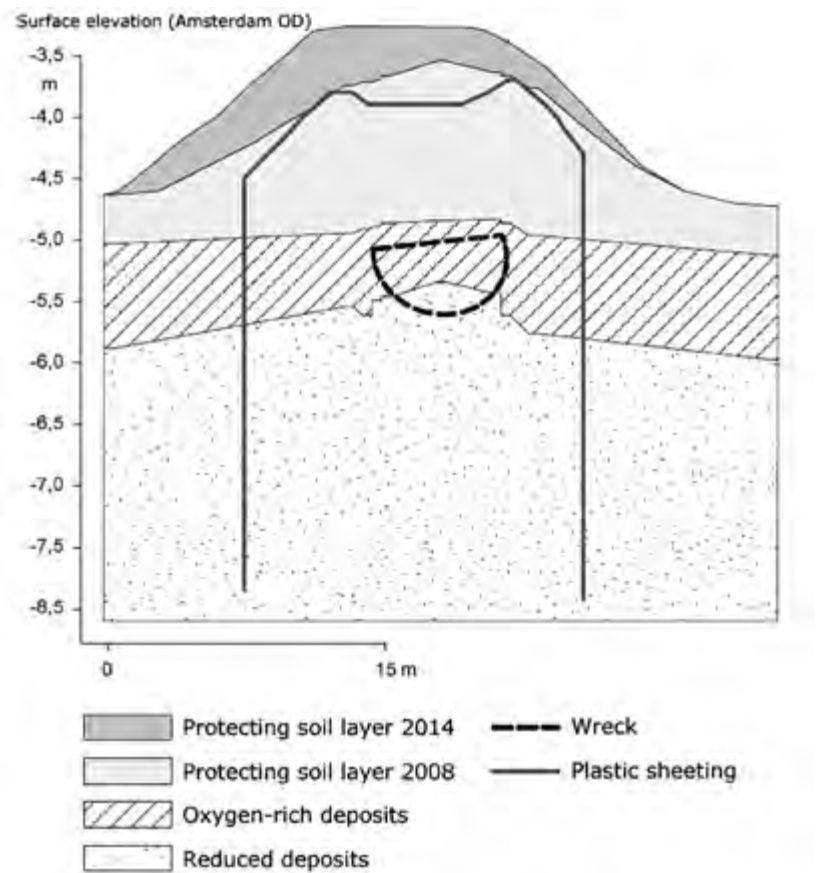


Fig. 6.8 Cross section of a wrapped and clamped wreck, Paradijsvogelweg (after Speleers *et al.* 2016).

archaeological remains.⁴¹⁹ A higher groundwater level will create more wetland, an environment favourable to reed-bed or carr vegetations. The deep and powerful root systems of reed can penetrate into archaeological layers (Section 4.4.4), and the tree roots in a carr can have the same disruptive effect.⁴²⁰

A highly localized form of hydrological management is 'wrapping up' archaeological remains. The *Rijksdienst voor de IJsselmeerpolders* ('National Agency for the IJsselmeer Polders') science department, for example, developed a technique for clamping wrecks and wrapping them in plastic foil.⁴²¹ This is based on the idea that evaporation and horizontal groundwater flow can be stopped by burying a wreck beneath a layer of soil and 'clamping' it in plastic sheeting until just below groundwater level so as to better conserve these ships' remains in the soil (Fig. 6.8).

⁴¹⁵ Even if the surface level of surrounding fields is lower than that in which a scheduled monument is located, an inundation partition, bank or retention dam around the site may still help to keep the groundwater at the desired level.

⁴¹⁶ See the policy document '*Deltaplan agrarisch waterbeheer*' ('Master Plan Agricultural Water Management') <https://agrarischwaterbeheer.nl/content/boerenstuwten>.

⁴¹⁷ Smit, Mol & Van Heeringen 2005c.

⁴¹⁸ Huisman & Mauro 2013.

⁴¹⁹ Soonius, Bekius & Molenaar 2001.

⁴²⁰ Cox *et al.* 2001.

⁴²¹ Reinders 2006; Speleers *et al.* 2016.



Fig. 6.9 Aerial photo of a new house with garage, Anjum, Noardeast-Fryslân Municipality (photo: Jos Stöver/erfgoedfoto.nl, National Monument 45.901).

6.6.4 Vegetation control to mitigate desiccation

Studies of physical measures to prevent the desiccation of peat and clay dikes indicate a vegetation cover of very low-growing species to be the most effective.⁴²² The shallow roots of such species absorb the least amount of water for evaporation, and this will significantly enhance soil saturation levels. The best method to keep the roots short is through grazing/pasture. Oostindie *et al.* (2003) have shown that weekly mowing will increase soil humidity while less frequent mowing barely makes a difference. When opting for grazing it is important to monitor for damage to the vegetation under dry conditions, for a defect in the vegetation cover will decrease soil saturation levels.

⁴²² Oostindie *et al.* 2003.

⁴²³ Roorda & Stöver 2016, 15 ff.

6.7 Archaeology-friendly construction

On archaeological national monuments archaeology-friendly construction, i.e. construction without damaging the subsurface archaeology, is rarely possible. Many construction-related activities, such as excavating construction pits, raising shallow foundations, surface reinforcement, heavy-vehicle traffic, or foundation piling and raising the building surface, put the monument at risk. To avoid damage to a monument due to earth-moving activities it is recommended to observe a buffer zone of at least 30cm above the top of the highest archaeological level. Digging into this buffer zone should be avoided (Section 6.4.2). This method contributes to the site's long-term conservation, for future interventions such as the demolition and removal of subsurface building components can be carried out without disturbing the site itself.⁴²³



Fig. 6.10 The terp Weiwerd near Delfzijl, a scheduled archaeological monument since 1968, was situated a stone's throw from an industrial area for which the village had to make way; many houses were demolished. However, the industry never materialized, and clever adaptive reuse has enabled the safe preservation of the subsurface archaeological remains (National Monument 45.306).

Occasionally, shallow foundations are an option (Section 6.7.2). A good example is a new house with garage on top of a raised house platform near Anjum, province of Friesland (National Monument 45.901, Fig. 6.9). A strip foundation was used for the house's timber frame construction; for the garage a slab-on-grade foundation sufficed.⁴²⁴ Sometimes old foundations can be reused. This is not (yet) common practice but it is technically feasible; new buildings on hospital grounds with subsurface remains of the Roman town of Forum Hadriani (see above) in the town of Voorburg were erected on the old foundations of the demolished former nurses' dormitory. For other examples, see e.g. Van Os *et al.* 2016 on the (re)development of the Utrecht Dom Square.⁴²⁵

6.7.1 Preventing strain-related damage

On sites with archaeological remains immediately below the surface, construction without disturbing the remains is possible only after the surface has been sufficiently raised (Section 6.4.2). This applies particularly to instances when the subsurface depth of the archaeology is less than 80cm -GL. Raising the surface makes it possible to place pipes and shallow foundations in this added layer of soil so as to minimize or even prevent disturbance of the site. A such, raising the surface will often resolve the issue of soil disturbance. Consolidation assessments can determine how much soil can safely be brought in without causing distortion of the underlying archaeology. A site-wide, 50cm-deep cover usually causes little or no consolidation and in the case of e.g. utility trenches is enough to prevent soil disturbance.⁴²⁶

⁴²⁴ Roorda & Stöver 2016, 18-21.

⁴²⁵ <https://praktijkvoorbeelden.cultureelerfgoed.nl/praktijkvoorbeelden/weiwerd-wordt-brainwierde>.

⁴²⁶ Roorda & Stöver, 2016, 42 ff.



Fig. 6.11 Marker at the site of a wreck, Zeewolde, in this case a caravel from the second half of the 16th century. An extra layer of soil has been applied to the site.

6.7.2 Building constructions

Soil strain caused by the weight of a construction can be reduced by reducing the weight, for instance by using lighter materials (e.g. timber frame constructions) or by reducing the mass of the building. Shallow foundations are particularly suitable for lighter constructions. Hybrid foundation techniques, in which part of the construction rests on a shallow foundation and part on foundation piles, also limit the extent of the disturbance. Slab-on-grade foundations are better suited to spreading the load than strip foundations, and frost-protected slab-on-grade can be made shallow. However, on soils susceptible to consolidation slab-on-grade is often not possible so that piling cannot be avoided. In that case it might be possible to adjust the piling plan so as to minimize the number of piles.⁴²⁷

⁴²⁷ Roorda & Stöver 2016, 23 ff.

⁴²⁸ Anderson 1985; Thorne 1989; Bergstrand 2002; Stanley-Price & Burch 2004; Demas 2004; Reinders 2006; Speleers *et al.* 2016.

6.8 Damage due to trenching

If is necessary to minimize soil disturbance (or if trenches are not an option) pipes and cables are increasingly being installed by directional drilling, a technique mainly used below roads and waterways but also below scheduled monuments. Directional drilling for electricity cables or sewers well below archaeological monuments is quite common. Cables and pipes can also be combined in one trench, preferably an existing one.

6.9 Covering and/or clamping archaeological remains

The main argument to cover an archaeological site is that it prevents the deterioration of fragile organic remains (such as wrecks) due to tillage and/or desiccation (Fig. 6.11).⁴²⁸

Studies of physical measures to counteract the desiccation of peat and clay dikes indicate that a clay cover helps to maintain a high soil water content, as does low vegetation with shallow root systems.⁴²⁹ The development of the scheduled monument De Horn (a Merovingian cemetery) in the Rijnsburg housing development is a good example. The area of the scheduled monument used to be part of a greenhouse complex but today is a public park. When the park was laid out the monument was first raised with calcareous clay typical of the area before park development began.

Another argument for covering a site is to prevent damage by plant roots (Section 6.12) or by burrowing animals and soil organisms (Section 6.13). This can be achieved by applying a light root cloth, or heavier or mat-like root barriers, or a thin soil cover. Heavier types of root cloth will prevent burrowing, and they also strengthen the soil and keep it together. As a group these materials are usually called 'geo-textile'.⁴³⁰ In the past, galvanized wire mesh was used to prevent burrowing. Cellular concrete blocks have been placed inside and around Dutch megaliths to stop treasure hunters.

To minimize the risk of compression of fragile archaeological remains (e.g. artefacts, fragile surfaces) the cover should not be too heavy (see also Section 6.7.1),⁴³¹ and it is important to always monitor for potential negative (side) effects.⁴³² The risk of rutting or undesirable compaction, for instance, depends in part on how the cover material is applied.

6.10 Modified vehicle and equipment use

First of all, vehicle traffic on archaeological national monuments should be reduced to a minimum. Second, to avoid deterioration of the soil archive due to rutting or compaction, equipment can be modified so as to reduce the pressure on the surface to acceptable and manageable levels.⁴³³ This can be done directly or indirectly. Examples of indirect measures are altering access and outgoing routes, or opting for work conditions during which the soil is less susceptible to rutting or compaction. Especially main routes and extremely wet conditions can



Fig. 6.12 On archaeological scheduled monuments, alternative methods to drag timber (e.g. draught horses or a caterpillar winch) may help to minimize damage or prevent it altogether (photo: Boosten & Penninkhof 2019, 79).

give rise to deep rutting and compaction.⁴³⁴ Examples of direct measures are (temporarily) placing duckboards or concrete slabs or another form of surface protection, or taking measures to reduce the direct axle load of vehicles and machines. Furthermore, escarpments may collapse if heavy agricultural machines, construction traffic or other heavy vehicles are driven too closely to the edge. In that case keeping a safe distance is a simple but effective way to prevent collapse.

⁴²⁹ Oostindie *et al.* 2003.

⁴³⁰ See also Hopkins & Shillam 2005.

⁴³¹ Roorda & Stöver 2016, 42. See also Muller *et al.* 2014.

⁴³² Thorne 1989; Van Heeringen, Smit & Theunissen 2004, 49; Speleers *et al.* 2016. See also Canti & Davis 1999, 776 and Huisman 2009.

⁴³³ Hanegraaf & De Visser 2003.

⁴³⁴ Oxford Archaeology 2002.



Fig. 6.13 Effect of tyres and tyre pressure on soil composition in a testing area (photo: Jos Swagemakers 2011).

When a route is changed the existing route is closed off for vehicle traffic – permanently or temporarily – to allow repairs. Building sites can be assigned a minimum of two access points which if necessary can be used in alternation, or by designating a wide access zone within which the route can be shifted. At the first sign of disturbance due to rutting or otherwise (see previous section) the access route should be relocated.

Clay and loam soils are most susceptible to disturbance by vehicles when the topsoil is saturated. Under those conditions the pressure between the soil particles is low and the soil consequently ‘weakens’ so that rutting and compaction may occur rapidly. A heavy downpour or the partial thawing of the topsoil after a period of frost can be enough to bring about such conditions. These situations are most likely to occur from October to March. Rutting can be avoided as long as traffic on the site at this time is kept to a minimum (see also Fig. 5.8b). These are the same the months when natural recovery of the grass cover by regrowth is limited.

Adjustment or closure of access and outgoing routes is feasible when a realistic alternative exists. If not, for example because there are few access routes, the options are to use lighter vehicles than the standard models or those in which the weight is distributed over a larger surface, for example by means of load-spreading tyres (see below).⁴³⁵ Other possible solutions are using draught horses, caterpillar winches or high winches to drag away felled timber (Fig. 6.12). Draught horses are particularly suited for work in small clearances.⁴³⁶

Rutting, slaking and soil compaction can be limited by modifying both tyre pressure and tyre width.⁴³⁷ Two examples will illustrate this. The strain on the soil is greatest in the case of a 5-tonne lorry with a tyre pressure of 7 bar. A 10-tonne thresher with a 2 bar tyre pressure, on the other hand, produces half as much strain, and if the tyre pressure is reduced to 1 bar the strain on the soil diminishes by another 25%.⁴³⁸ However, soil humidity significantly influences the effect of tyre pressure on soil strain, penetration resistance, and rutting. Under wet conditions, lowering the tyre pressure from 3 bar to 1 bar increases tyre penetration by one fifth whilst reducing rutting by one third, and soil

⁴³⁵ Van Iterson & Hendrix 2006; Smits 2010; Oxford Archaeology 2010, Appendix 1; D’Hose *et al.* 2017.

⁴³⁶ Boosten & Penninkhof 2019.

⁴³⁷ Hanegraaf & de Visser 2003, 27, 57; D’Hose *et al.* 2017; Van Iterson & Hendrix 2006.

⁴³⁸ Godwin *et al.* 2010.

strain by one sixth.⁴³⁹ Under dry conditions the effect on rutting is smaller while that on tyre penetration and soil strain will be greater.⁴⁴⁰

One option is to reinforce the intended traffic surface; duckboards are a well-known solution. More permanent, traditional options are permeable asphalt or gravel; alternatives are granulate or concrete cellular blocks (cellular confinement systems), which allows grass to grow through them. Another possibility is improving the discharge of excess groundwater along access and outgoing routes. However, all these options have an impact on the soil one way or another, which may affect the monument. An alternative, and also permanent, solution which is less disruptive is sowing wide strips of grass species that are more tolerant of traffic. Geo-textile can be applied below the turf to further increase the load-bearing capacity.

6.11 Erosion prevention

Erosion cannot always be entirely prevented. Most anti-erosion measures are a compromise between what is physically necessary, technically feasible, and economically viable. Many solutions to control slope erosion also require changes in farming practices. In some cases it may be possible to carry out the necessary interventions outside the archaeological monument, further upslope. Consultation with and the cooperation of the involved farmers and landowners are crucial. Measures should always be effective in the given situation, but cost efficiency is also an important consideration. Occasionally soil erosion can be a positive process from a nature conservancy perspective, for instance in the case of drift sands or in some dune areas.

6.11.1 Cultivation techniques to prevent run-off soil erosion

In general, a dense vegetation cover with a well-developed root layer (e.g. grass species) provides optimal protection against soil erosion, while tillage (especially ploughing) and leaving the land to lie (partly) fallow accelerate the

erosion process (on laying fields fallow, see also Section 6.4.3).⁴⁴¹ Crucial factors in soil wash are slope inclination and slope length. Cultivation techniques which can prevent soil erosion should meet the following criteria:⁴⁴²

- They contribute to a good aggregate structure;
- They increase the unevenness of the soil surface;
- They ensure maximum soil coverage, both in quantity and in time.

A well-developed aggregate structure is better able to withstand the erosive impact of raindrops (so that slaking or crustation are less likely to occur) or the erosive force of run-off water (so that soil particles will wash away less easily). An uneven surface slows down run-off and because of its unevenness is also able to absorb more water, giving it time to infiltrate the soil. Together, these effects will decrease the risk of soil erosion. For an uneven surface the seedbed needs to be prepared as coarsely as possible, surface rutting should be removed by hitching a cultivator behind the tyres, and after the harvest the soil should be superficially treated to remove slaking. The soil should preferably be worked in dry conditions, to prevent compaction. Crops and crop residue also protect the surface from being directly hit by raindrops, and they also slow down run-off. In addition, a greater supply of organic matter and root development will benefit soil organisms, improve the soil structure, increase infiltration, and prevent slaking and soil erosion.

A classic technique to create an uneven soil surface is contour tillage. Contour tillage means ploughing, harrowing and sowing parallel to the slope.⁴⁴³ However, contour tillage is only possible on slopes with an inclination less than 8%.⁴⁴⁴ Although the technique does slow down erosion it does not lessen the physical impact of ploughing (e.g. on subsurface archaeology or micro-relief). Other methods to reduce erosion are undersowing and double sowing. ‘Double sowing’ means sowing twice in run-off zones where rilling is a common occurrence.⁴⁴⁵ In undersowing, a cover crop is sown under the main crop, e.g. grass used as a cover crop in a maize field.

⁴³⁹ D’Hose et al. 2017, 49.

⁴⁴⁰ Ibid.

⁴⁴¹ E.g. Geelen 2006; Hessel, Stolte & Riksen 2011.

⁴⁴² Hessel, Stolte & Riksen 2011; ALBON 2015.

⁴⁴³ Gillijns et al. 2005: 33; ALBON 2015.

⁴⁴⁴ Ibid.

⁴⁴⁵ Gillijns et al. 2005, 33.



Fig. 6.14 Grass zones, province of Limburg, Belgium
(photo: <http://www.limburg.be/Limburg/waterlopen/ABC/Landbouw-en-natuur/Grasstroken.html>).

Other techniques which can significantly reduce soil erosion are non-reversal tillage and no-till cultivation (Section 6.4.1), as has been convincingly demonstrated in recent field experiments (rain simulations) and field monitoring (erosion mapping) in Flanders, Belgium. It was concluded that non-reversal tillage can reduce field erosion by more than 85%.⁴⁴⁶

6.11.2 Other measures to prevent run-off soil erosion

Grass buffer zones and grass corridors

Grass buffer zones and grass corridors (Fig. 6.14) break the force of the run-off and intercept some of the eroded sediment as well as providing local protection against soil erosion. Grass buffer zones are laid out perpendicular or obliquely to the direction of the run-off; grass corridors are made to follow the direction of the run-off, usually in depressions where water accumulates naturally and rilling is most likely to

Erosion prevention regulations in the hills of the province of Zuid-Limburg.

Until 2014 erosion prevention regulations in the hills of Zuid-Limburg were part of a by-law issued by Productschappen Akkerbouw en Tuinbouw ('Commodity Board for Agriculture and Horticulture').⁴⁴⁷ After the Board was discontinued the regulations were adopted unchanged by the Ministry of Economic Affairs. Today, they are part of the conditions under the EU's Common Agricultural Policy to qualify for a Single Payment Scheme.⁴⁴⁸ The erosion prevention regulations are contained in Article 3.1 Section b and in Appendix 4 Section 4 of the Common Agricultural Policy.

The Zuid-Limburg regulations state that erosion-sensitive crops should not be grown on slopes with an inclination in excess of 2%, except when non-reversal tillage is combined with a cover crop. A cover crop is sown immediately after the harvest but no later than 15 October of that same agricultural year, and during the winter stays on the field either as a living crop or as a crop residue which is lightly ploughed or left on the surface. Exceptions to this regulation are allowed only if measures are taken that are at least as effective as non-reversal tillage and a cover crop. The erosion prevention regulations apply to horticultural fields situated entirely or in part within the boundaries of the province of Zuid-Limburg south of the Sittard-Wehr (until the Dutch-German border) and Sittard-Urmond (until the Dutch-Belgian border) motorways, with the exception of the winter channel of the river Meuse and the floodplains of the rivers Geul and Gul. The regulations contain general instructions which apply to all fields in this area including those on level terrain. Other important mandatory activities are:

- Autumn tillage; this can be omitted in the case of a (grass) vegetation cover and perennial crops.
- Erasing the ruts left by tractor tyres, except when cover crops are cultivated by means of direct sowing in spring.
- Regarding fields on an 18% inclination or steeper: conversion into or continuation as grassland.
- Erosion and excess water in the case of linear or surface-wide erosion to a depth in excess of 12cm should be reported immediately.

In addition, current regulations regarding the conservation of landscape elements (including hedges, ditches, tree lines, spinneys or isolated trees, field edges and terraces) also apply.

⁴⁴⁶ ALBON 2015, 23.

⁴⁴⁷ Verordening PT erosiebestrijding Zuid-Limburg 2013.

⁴⁴⁸ Uitvoeringsregeling rechtstreekse betalingen GLB.

occur. It is important that rill formation alongside the grass zones is stopped at once; if it does occur the rills should be erased.

Copses, hedges, wooded banks and embankments

Other useful elements to prevent erosion are copses, hedges, wooded banks and embankments. They stop run-off, intercept sediment, and break the length of the slope. The presence of an embankment in the landscape will also reduce the inclination of a field. Erosion is less likely to occur near and downslope from such small landscape elements.

Dams

Run-off water and sediment can also be temporarily stored behind dams, to be built in places where run-off accumulates.⁴⁴⁹ Dams can also be used to divert run-off and sediment towards a retention basin further downslope (see below). The further upslope in the run-off zone the dams are positioned, and the closer to the source the water is retained, the more effective this measure will be.

Dams built of vegetable material such as withies, bales of straw or coconut fibres, or cut branches are suitable only for run-off zones smaller than 5ha. This type of dam is often placed in grass corridors to slow down run-off even more. Other advantages of using vegetable matter for dams are cost efficiency and the fact that they are relatively simple to build. A disadvantage is their short use life; coconut-fibre dams last five to eight years, those made of withies last only three years, while woodchip dams need to be refilled every two or three years. Dams made of loppings need to be refilled every two or three years. Dams made of earth last much longer. Except for occasional mowing dams require little maintenance.

Water retention basins

Water retention basins are excavated receptacles for water and sediment. They can be built outside the archaeological monument that is at risk. Sediment remains in the basin while water is gradually released via a pinch pipe towards a downslope watercourse, either directly or via another pipe. Water retention basins are expensive to construct and maintain. Regular removal of the sludge is necessary to ensure their effectiveness.

6.11.3 Prevention of wind erosion

Measures to prevent wind erosion usually focus on one or several of the three main factors responsible: an exposed soil surface, insufficient soil particle cohesion, and/or high wind speeds at surface level. Possible solutions include:⁴⁵⁰

- Keeping the soil covered;
- Increasing soil particle cohesion;
- Reducing the local wind field.

Measures such as minimal tillage (non-reversal tillage), crop rotation, and keeping exposed soils covered are effective on arable fields; winter crops or green fertilizers can be used for this purpose. Another method to prevent wind erosion on arable is the application of a protective cover, such as paper pulp which is spread on flower-bulb fields during the fallow season. Soil particle cohesion can be improved by raising the organic matter content. The primary purpose of features such as windbreaks, sand fences, or alley cropping is to reduce the wind field. Suitable long-term solutions are reducing field size, planting windbreaks, and converting arable to grass, but these impact directly onto farming practices.⁴⁵¹

⁴⁴⁹ ALBON 2015, 29.

⁴⁵⁰ Wagelmans 2002; Hessel, Scholte & Riksen 2011, 31-33.

⁴⁵¹ See also Wagelmans 2002.



Fig. 6.15 In the past, access to the Hunenborg site (Volthe, province of Overijssel) was difficult, and the monument was barely visible and therefore not very attractive to visitors. The area was overgrown with trees and shrubs, and frequent windfalls had a disastrous impact on the archaeological remains. To remedy the situation, an ongoing project for the past few years has been attempting to make the Hunenborg site more accessible to the general public. Measures to ensure the monument's long-term conservation include the removal of trees and frequent mowing. Archaeological research was carried out prior to the project (National Monument 46.005, cross section through the bank; see also Fig. 4.7. Photo: RAAP).

6.11.4 Erosion prevention on man-made slopes (mounds, mottes, banks, and terps)

Man-made platforms with a steep slope (e.g. mottes, high terps with escarpments, and escarpments on former fortifications) are highly susceptible to soil erosion and subsidence (and trampling) (Fig. 4.4).⁴⁵² Because the slope profile is an important element of a monument's experience value, any defect to it will quickly qualify as damage.

Small defects on (and/or digging-scars in) slopes due to trampling, subsidence or burrowing animals can rapidly lead to further, more substantial erosion. Caution is therefore needed when removing the vegetation on such slopes, because the roots provide solidity. Repairing the affected slope takes priority.⁴⁵³ This may take the form of filling in gaps with sand and sods (to prevent subsidence) and placing grass on top.⁴⁵⁴ The sand should be brought in from outside, so that future archaeologists will

be in no doubt as to what is and is not part of the original structure. Following several subsidence episodes in 2006 - 2008, defects on the terp Wierum, near Adorp (province of Groningen) were filled in with dredging spoil from Starkenborgh Canal. Other options beside repairing affected slopes are restoration and reconstruction. It should be noted here that larger repairs carried out on national monuments, such as filling in pits larger than 1m³, are subject to a monument permit.

Slope subsidence can be prevented by reinforcing the topsoil/surface or by stabilizing the subsoil.⁴⁵⁵ Reinforcement of the topsoil is preferred because this can usually be achieved without disturbing the subsoil. Methods include applying open wire-mesh, sowing ground-covering species with stronger root systems, or applying a new top layer to eroded and erosion-prone zones. Repairing water-conducting elements such as old paths and hedges at the top of the slope help to prevent slope erosion. If this is insufficiently effective the following additional measures may be considered:⁴⁵⁶

⁴⁵² Van Doesburg & Stöver 2018.

⁴⁵³ Berry & Brown 1994; Rimmington 2004.

⁴⁵⁴ Groenendijk & Meijering 2006.

⁴⁵⁵ Abramson *et al.* 2002; Postma 2010. See references in Van Doesburg & Stöver 2018. See also Shockley 2000;

Rimmington 2004; Stewart 2013, 93.

⁴⁵⁶ *Ibid.*

- Drainage ditches and water-conducting elements to prevent rainwater from penetrating into the slope;
- Inserting reinforcements of parallel or radial rows of posts ('ground nailing');
- Placing a geo-cell covering on the surface;
- Constructing buttresses/shoring at the foot of the slope.

At defensive sites with their associated moats or ditches both earthen banks and ditches are at risk from erosion, which will level the banks and fill in the ditches (see also Fig. 4.3).⁴⁵⁷ If groundwater levels are lowered moats may fall dry and embankments may start to compact or sink into the subsoil, which after desiccation loses its load-bearing capacity.

6.12 Vegetation control

6.12.1 Trees

If trees are growing on a national monument it is important to check at regular intervals whether or not they are becoming a threat to the archaeological remains.⁴⁵⁸ Possible measures to prevent tree-related damage (root action, windfall) include the gradual removal of the trees, regular maintenance of the crowns, diverting the root systems, and repairing holes in the surface.⁴⁵⁹ The stability of individual trees can be improved by gradually clearing the surrounding area. Side branches can be pruned back to the main branches so as to reduce the tree's susceptibility to windfall; or the crown can be made lower.⁴⁶⁰ The latter measure is particularly effective to prevent windfall. Kuiper & Van Schooten (1985) and Crow & Moffat (2004), among others, discuss other measures to minimize the risk of windfall.

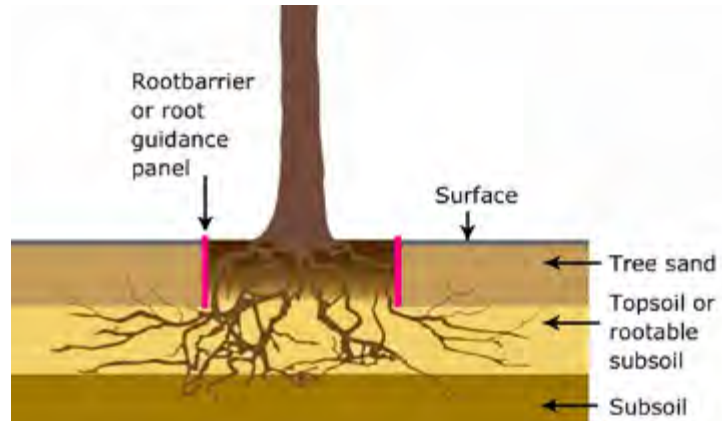


Fig. 6.16 A controlled root system (after Brouwers 2015).

Sometimes removing the heaviest vegetation is the best option (Fig. 6.15), but not always, as when the vegetation keeps an escarpment from crumbling; this was the case at the motte castle of Eys, province of Zuid-Limburg (National Monument 528.935). After felling, a rotting tree trunk can weaken the stability of a slope; in some recorded instances, the removal of vegetation (including trees) rather than preventing erosion made it worse (e.g. on the terp Oostrum). Prior to a decision about the removal of trees it is important to assess whether the tree roots are strengthening (for instance) a slope and preventing erosion, or whether root action and the chance of windfall constitute a physical threat.

Clearing in itself can be a seriously disruptive intervention on a national monument. After felling, the stubs and root balls must be left in the soil so as not to disturb the soil archive. Tree trunks are preferably sown off as close to the surface as possible, for a stub attracts all kinds of burrowing animals. Felling usually requires a permit from the local Council, and relevant legislation with regard to flora, fauna and forestry should be considered.

⁴⁵⁷ Rimmington 2004; Baas & Raap 2010, 1.139.

⁴⁵⁸ Van Ginkel & Groenewoudt 1990; Mauro 2001; Russell 2003; Van Eerden 2004; Baas & Raap 2006/2010; Boosten & Penninkhof 2019, 75.

⁴⁵⁹ Crow & Moffat, 2004; Baas & Raap 2006/2010, Chapter 3: *Cultuurhistorische beheermodellen*.

⁴⁶⁰ Kuiper & Van Schooten 1985.



Fig. 6.17 Reed plume and stem (photo: Midwest Herbaria, CreativeCommons).

6.12.2 Root suppression and root control

In the absence of regular maintenance, rampant vegetation or tree species with widely expanding root systems can become a threat. Damage by root pressure can be prevented by diverting specific root sections to deeper levels

by means of so-called root guidance panels with vertical ribbing.⁴⁶¹ Below the panel the roots can resume their natural course, which allows firm anchorage without damage to structural remains.⁴⁶²

⁴⁶¹ Moffat, Bending & Dobson 1998; Greenmax 2016; Hendriks 2019.

⁴⁶² Wagar & Barker 1993.

However, root activity may also threaten deeper subsurface archaeological remains. In that case a geo-textile root barrier can be placed (Fig. 6.16).⁴⁶³ Made of for instance root cloth or HDPE foil, the smooth surface of the barrier blocks root growth, forcing it towards shallower levels. In built-up areas root barriers are used to protect for instance subsurface utilities against root damage. Past experience indicates that as long as the roots find a suitably permeable zone they will continue to grow at the desired depth. Root suppression was used on for example the Roman road along the former *limes* in the newly developed Utrecht housing estate Leidsche Rijn. In this case, horizontal root cloth was used rather than vertical root barriers.

6.12.3 Wildshoot prevention

Wildshoot prevention (shrubs, trees) on archaeological national monuments, particularly those that are visible, is equally important.⁴⁶⁴ With timely maintenance it is possible to avoid having to resort to more radical means to get rid of young trees. When removing or thinning shrubs it is best to saw or mow as close to the surface as possible, leaving the root ball intact. Subsequent treatment of the remaining stubs is essential, for pruning can enhance growth vigour and stimulate regrowth.

Vehicle traffic can cause rutting and soil compaction and if unavoidable should be limited to situations when the soil conditions allows it, i.e. neither too dry not too wet (Section 6.10). Pulling saplings is effective but time-consuming, and since the root ball is also removed repeated pulling may damage a considerable section of the topsoil. Wildshoot control should therefore be carefully managed so as to prevent further deterioration.

Grazing in spring and early summer by sheep or goats can also reduce regrowth and kill saplings. However, intensive grazing can have a negative impact in the form of trampling and erosion. A possible solution is root cloth to prevent regrowth. This requires a substantial initial investment, but the subsequent annual costs of monitoring and perhaps removing some growth along the edges are limited.⁴⁶⁵

6.12.4 Reed control

In open field and in or near open water, reed (*Phragmites australis*) is very difficult to remove completely. The species is highly rampant and can grow at different depths, which makes it very hard to control (Section 4.4.4).⁴⁶⁶ In some cases (but only outside an archaeological monument) digging or pulling (manually or with a backhoe) is the easiest method, but this is not possible in archaeologically sensitive areas. Reed can also be controlled with an herbicide, but most substances are not acceptable in the context of a nature management. The most effective method is to prevent reed from spreading by mowing before the winter to remove the seed plumes, although mowing will stimulate young shoots in spring. If the reed is growing in water, repeated mowing below the water surface during the growth season is helpful because the hollow reed stems will fill with water and die off. This will weaken the parent plant and ultimately kill it. Stichting Flevolandschap has carried out grazing experiments with various animals including horses.

⁴⁶³ Morgenroth 2008; Greenmax 2016.

⁴⁶⁴ Baas & Raap 2006/2010, Chapter 3.

⁴⁶⁵ See also Oldenburger et al. 2017.

⁴⁶⁶ Mauro 2001; Van Eerden 2004; Tjelliden et al. 2016.



Fig. 6.18 Rabbits at their warren.

6.12.5 Exotic species

Oldenburger *et al.* (2017), among others, tried to establish what would be the best method to control rampant, deeply rooted (and so undesirable) exotic species. Biweekly mowing with a combination of a vacuum mower, manual mowing (brush cutter, scythe) and grazing by sheep turned out to be expensive, while monthly mowing with a vacuum mower in combination with stub treatment was relatively cheap. Covering (with root cloth or other suppressant materials) requires a substantial initial investment, but the subsequent annual costs of monitoring and perhaps removing some stems along the edges are limited. Digging out and/or pulling out the entire plant including the root ball appear to produce good results, but these methods are not suitable for archaeological monuments.

6.13 Preventing damage by wild animals and livestock

6.13.1 Introduction

Some forms of nature management and agricultural exploitation on archaeological national monuments stimulate animal burrowing. If rabbits and rats are living on a

monument the first recommended course of action is to make sure natural predators can enter the burrows.⁴⁶⁷ Fencing off archaeologically sensitive sections of the monument will help to prevent rooting by wild boar or other animals.⁴⁶⁸ The presence of protected species such as badgers calls for careful monitoring of the extent of the damage and taking additional protective measures when necessary. To prevent future damage it is important to focus on the causes of the presence of these animals.⁴⁶⁹ Placing wire mesh below the grass or the sod cover will prevent a reoccurrence.⁴⁷⁰ The publication *Handreiking Faunaschade* 2009 ('Damage due to Animal Action Guide') and the website *Faunaschade PreventieKit* ('Animal-related Damage Prevention Kit'; discussing each species separately)⁴⁷¹ present a detailed review of measures that could be taken to prevent damage due to animal activity. The next section is a brief summary of the information contained in these two sources.

6.13.2 Rabbits and badgers

Preventing rabbits from burrowing in an archaeological monument is far from easy. The best ways to control a rabbit infestation on a national monument are removal and exclusion.⁴⁷² First, further population increase has to be stopped. Methods to achieve this include making the warren accessible for natural predators, shooting or trapping the rabbits,⁴⁷³ smoking them out, introducing ferrets, or using poison gas.⁴⁷⁴ Migration from nearby populations should be prevented; this can be accomplished by placing nets or a closed barrier.

Badgers are a protected species and should not be captured, relocated or killed, except by licence. As in the case of rabbits, altering favourite habitats is the best way to prevent a badger family from moving in. For example, if shrubbery and bracken are removed the animals will find less shelter or suitable bedding for their den. Badgers are very shy so that creating new access routes around a monument will scare them off. In combination with improving their habitat outside the monument, this can be an effective measure to limit badger damage. In the event the relocation of the badgers is necessary

⁴⁶⁷ Russell 2003; Rimmington 2004, 65.

⁴⁶⁸ Boosten & Penninkhof 2019, 76.

⁴⁶⁹ Dunwell & Trout 1999, 8.

⁴⁷⁰ Baas & Raap 2006/2010, 3.87.

⁴⁷¹ Oord 2009 and www.bij12.nl/onderwerpen/faunazaken/faunaschade-preventiekit-fpk/, respectively.

⁴⁷² Dunwell & Trout 1999, 8; Rimmington 2004, 65.

⁴⁷³ Snares and traps may inadvertently catch other animals as well, including pets.

⁴⁷⁴ For exclusion and removal methods in an archaeological context, see Rimmington 2004, 65-67. On one occasion, Cultural Heritage Agency of the Netherlands has already granted a subsidy for the use of ferrets, in the context of the *Subsidieregeling Instandhouding Monumenten* ('Monument Conservation Subsidy Scheme').

to prevent soil disturbance on an archaeological national monument, by law the appropriate organizations should be consulted first.

6.13.3 Moles and rats

If mole activity is disturbing an archaeological monument the best way to remove the animals is by placing a conibear or other type of trap.⁴⁷⁵ Placing them requires no specialist training. Mole tunnels close to the surface should be used, and digging to place the traps should be avoided on monuments with archaeological remains at shallow depth. Traps can also be used preventively to create a buffer zone around archaeologically sensitive sections of the monument. Another option is to use earthworms laced with poison. Controlling moles and water voles by chemical means (aluminium phosphide or magnesium phosphide tablets) is allowed only under strict conditions and requires a specific licence.⁴⁷⁶ Excluding or repelling the animals are also the best methods in the case of rat and muskrat activity, in combination with population control.⁴⁷⁷

6.13.4 Preventing soil disturbance by livestock

Measures to prevent soil disturbance by livestock on archaeological national monuments include lessening the impact of grazing, protecting particularly susceptible locations, or fencing off and repairing damaged areas.⁴⁷⁸

The purpose of lessening the impact of grazing on an archaeological monument is to control the disruptive aspects of grazing on the soil and micro-relief, such as erosion and trampling (Fig. 6.19). This can be achieved by reducing the number of animals per surface unit, or by introducing seasonal restrictions (no grazing during the wet season, for example), depending on local conditions and options. These measures are also applicable to grazing in the context of nature management.⁴⁷⁹



Fig. 6.19 Trampling by livestock on a dike surface (photo: Deltares).



Fig. 6.20 Timber revetments mark an access point through a bank and at the same time keep the surface from crumbling. A timber palisade marks out the bank's course.

Permanent or temporary fencing may be necessary if soil disturbance has reached a point where intervention is urgent, for example when shallow archaeological levels are visibly exposed, or when either the monument's appearance or the wider landscape setting (i.e. the experience) have been affected. Temporary forms of fencing (e.g. electric) can be used to protect (parts of) the monument from grazing while the grass turf is allowed to recover or is

⁴⁷⁵ Dunwell & Trout 1999, 9; Rimmington 2004, 62 ff.

⁴⁷⁶ See also www.bij12.nl/onderwerpen/faunazaken/faunaschade-preventiekit-fpk/module-woelmuisen-ratten-en-mollen/#2.3. See also Rimmington 2004, 62 ff.

⁴⁷⁷ Ibid. Dunwell & Trout 1999, 9.

⁴⁷⁸ Van der Heiden & Feiken 2018; See also Crofts & Jefferson 1999, Chapter 5.

⁴⁷⁹ Rimmington 2004, 41 ff.; Crofts & Jefferson 1999, Chapter 5.



Fig. 6.21 This sign warns the public not to climb on megaliths (photo: Hunebedcentrum).

re-sown. Permanent fencing is an option when other measures have failed to solve the problem, or if there is no feasible alternative.

Another option is to use fencing to change a field access point or the route to a feeding station or water trough, or any other of the livestock's favourite's tracks. Concrete slabs can be placed at points where cattle can cross from one field to the next. In sections that are susceptible to trampling but where options are limited, the subsoil can be reinforced by a layer of gravel or granules on top of permeable geo-textile. If the livestock's frequent use of a favourite resting place threatens to damage the soil, alternative shade or shelter can be provided; it may be enough to simply remove low branches, cut back a tree crown, or remove rubbing places (posts or walls).

6.14 Recreation management

Two types of recreation management on archaeological national monuments can be distinguished: reinforcing the surface (e.g. grass vegetation, path surfaces) against wear, and altering or at least controlling the flow of visitors (guided routes).

6.14.1 Surface reinforcement

Reinforcing paths and creating a more robust vegetation cover will make the site surface more resilient against traffic. There are several ways to achieve this: changing the grass turf (e.g. by sowing English ryegrass, *Lolium perenne*), enhancing the grass' vitality, preventing flooding, and watering sections that are prone to dry out.⁴⁸⁰ Severely eroded sections can be filled in with sandbags or plain sand and covered with geo-textile, to keep the soil in place while the vegetation is recovering. Another option is to apply semi-hard materials such as (clay) gravel. The type of material (wood chips, bark, soil, grass turf, aggregates) depends on the specific nature of the location and on possible future interventions.

⁴⁸⁰ See also Rimmington 2004, 11 ff.



Fig. 6.22 The Burchtheuvel monument, originally a motte; Leiden (National Monument 532.258).

6.14.2 Altering or controlling routes

Altering or controlling routes, whether permanently or for a shorter period of time, is yet another method to prevent erosion damage and compaction. Permanent paths are a means to steer visitors in a specific direction, away from fragile places, but they can also be used to draw them towards a location so as to scare off wild animals which might otherwise cause damage

(Section 6.12). Routes can be relocated or regularly moved (in the case of walking trails) by shifting guide ropes, electric fencing, or wooden guide posts. Routes can also be marked by mowing. Another erosion-prevention measure is the seasonal closure of parking lots or access routes during the most precarious periods. It is recommended to use aerated and water-permeable granulation or open paving (e.g. cellular blocks, grass concrete) as a basis for parking lots.

6.14.3 Vandalism prevention

Physical protection of an archaeological monument from illegal digging by metal detectorists can be provided by covering sensitive sections of the site with root cloth, wire mesh, or gravel.⁴⁸¹ Locations which attract vandalism can be protected by a fence or other type of barrier, such as open paving on top of vulnerable soil layers. It is important, however, to ensure that the site remains attractive to visitors. There will always be some tension between, on the one hand, closing off (sections of) an archaeological monument and, on the other, opening them up to the public. This is why, in 2018, landscape organization Drents Landschap and archaeological museum Hunebedcentrum initiated an information campaign to discourage the public from ‘recreational’ climbing on top of the Drenthe megaliths (Fig. 6.21). The publication ‘EHBO hunebedden’ provides guidelines as to what to do when confronted with damage to megaliths and/or the surrounding site.⁴⁸²

6.15 Measures specific to certain complex types

Today, visible archaeological remains constitute the largest group of scheduled national monuments. Many of the physical measures to prevent damage to this type of monument have already been discussed in the previous sections. For instance, for physical conservation measures on man-made mounds/mottes and banks, see Sections 6.12 (Vegetation control) and 6.11.4 (Erosion prevention on man-made slopes (mounds, mottes, banks, and terps). The next section will present a series of complex types which require specific measures.⁴⁸³ Some of these measures were discussed earlier, but because of the specific nature of these complexes the measures will be summarized once more.⁴⁸⁴

- Castles, monastic sites, churches, granges;
- Ringforts, refuge mounds, mottes;
- Terps;
- Celtic fields;

- Earthen banks, rural fortification systems, sconces;
- Burial mounds, urnfields.

6.15.1 Castles, monastic sites, churches, granges

Castle sites in rural areas, especially those with visible remains but also subsurface sites, often suffer from regular agricultural usage (periodic ploughing, spading, livestock grazing).⁴⁸⁵ Ploughing and spading can damage valuable layers and features while grazing may cause erosion on escarpments where livestock sometimes create depressions in the surface, as for instance on the mottes of Westkerke (on the island of Tholen; National Monument 526.851) and Biggekerke (National Monuments 46.135, 46.136, 46.138). Castle sites in woodland areas are sometimes affected by root pressure from the vegetation growing on the site. Tree roots can erase soil features and break up masonry. Also windfall can cause damage, as the toppling root balls drag soil sections with them.

Some of the suitable countermeasures are identical to what applies to banks (Section 6.15.4) and burial mounds (Section 6.15.5): trees should be removed from foundations and masonry, holes and gaps should be filled in with ‘clean’ soil and covered with sods, sensitive areas should be marked, paths and roads diverted. Removal of the densest overgrowth is often the best solution, but not always. Sometimes it is the vegetation which keeps escarpments from crumbling, as in the case of the motte site at Eys, province of Zuid-Limburg (National Monument 528.935). A possible solution for castle sites in rural areas is converting them into grassland, or fencing off mottes and other man-made platforms to keep animals out.

Moats and ditches are different from other visible castle site elements. Silted up moats/ditches can be restored to their original depth and sometimes be made to hold water again, provided any vulnerable archaeological layers are not affected. Caution is necessary, for although castle moats were also regularly cleaned in the Middle Ages, the infill can still

⁴⁸¹ Lauwerier & De Kort 2012.

⁴⁸² Van der Sanden *et al.* 2016.

⁴⁸³ See also Berry & Brown 1994; Rimmington 2004.

⁴⁸⁴ Baas & Raap 2006/2018. See also Boosten & Penninkhof 2019.

⁴⁸⁵ Cultural Heritage Agency of the Netherlands 2012b.



Fig. 6.23 Remains of the construction timbers of Iron Age houses, unearthed during the famous excavations on the terp Ezinge, province of Groningen, by Professor van Giffen between 1923 and 1934 (photo: Groningen University, Groningen Institute for Archaeology).

contain valuable archaeological remains such as household ceramics, building material, or remains of wooden revetments and bridges.

6.15.2 Ringforts, refuge mounds, mottes

The recommended maintenance regime for those ringforts that are national monuments (e.g. Hunneschans on Lake Uddeler, province of Gelderland, Fig. 2.8; or Huneborg, Volten, Fig. 4.7) is similar to that of burial mounds in a woodland setting. To maintain or improve the visibility of the earthen banks any undergrowth should be either controlled or removed. This should be done with care (Section 6.12). It is important to decide beforehand on the desired impression one wishes to achieve, and on possible negative consequences: root systems also keep the soil together.

Traffic from agricultural machinery poses no threat to the scheduled ringforts and refuge mounds. Damaged areas should be filled in and covered as described earlier, and measures should be taken to prevent a future reoccurrence. Paths or roads across or on top of the banks are not recommended, but it is not always possible to remove them (or to prevent them) depending on existing routes and access points. It may therefore be advisable in some cases to allow controlled access, as on the motte on the Grebbeberg plateau.

It is important that the turf on a motte remains intact to ensure the monument's preservation, as a strong turf cover prevents erosion (Section 6.11.4). New tree growth on a motte should be avoided; tree root pressure and windfall or subsidence will damage the site. A moat or ditch needs to be dredged every now and then, but not too deeply; it is best to dredge fairly often but always to a shallow depth. The original dimensions should never be exceeded.⁴⁸⁶

⁴⁸⁶ Baas & Raap 2006/2010 present a maintenance model for mottes, including those in Zeeland (where these structures are called vliedbergen).

6.15.3 Terps

Terps can be affected by various kinds of interventions.⁴⁸⁷ On the one hand, these relate to (past and present) building activities, repairs to damaged buildings, filling in and digging ditches, utilities trenches, and modern burials. On the other hand, there will also be gradual, invisible forms of deterioration, especially on vacant plots. Agricultural use may pose a threat to terps and the oldest archaeological strata at their base because many land users erroneously believe that activities such as (deep) ploughing, levelling, and drainage constitute ‘regular agricultural use’ and are therefore exempt from the requirement to apply for a permit (Fig. 5.3). A number of natural processes can also have a negative impact, such as desiccation, windfall, water erosion, and escarpment collapse (Fig. 4.4).

Current regulations with regard to permits to some extent work in favour of the long-term conservation of terps. Permit applications for construction projects on national monuments are regularly adjusted so as to safeguard the archaeological remains. However, quite often adjustment of the project plan is not an option, for example in the case of subsurface installations such as manure cellars or underground waste containers. In those instances the permit document will stipulate that construction activities must be preceded by an archaeological evaluation, ranging from archaeological supervision to a full-scale excavation.

Often the goal of the maintenance regime on a terp is to preserve its visual landscape qualities and its association with other nearby cultural historical landscape elements.⁴⁸⁸ It is therefore important to avoid wildshoots on slopes, and escarpment subsidence. One way to avoid damage on agricultural fields is to maintain sufficient distance from an escarpment. Trees often surround terp cemeteries and grow on them, and these will need to be properly maintained. Small surface

defects can be filled in. All these interventions require prior consultation with the Cultural Heritage Agency of the Netherlands and with the local Council. Other potential risks on terps are deep tillage and desiccation of the underlying archaeological strata. Research has indicated that valuable archaeological remains can be expected to be present even in terps that have been largely dug away (Fig. 6.2).⁴⁸⁹ Wooden construction elements (Fig. 6.23), bone and ferrous objects will deteriorate under aerobic conditions (Section 5.4.7). Deep tillage on the vulnerable archaeology at the base of a terp can be prevented by converting arable into grass (Section 6.4.4), or by adding extra soil (Section 6.4.2).⁴⁹⁰

6.15.4 Celtic fields

Careful maintenance is necessary to preserve the micro-relief of Celtic fields, which is highly susceptible to (gradual) soil loss. Because of this, most forms of tillage or other soil activities are extremely harmful to this type of archaeological national monument, including turf stripping and deliberate removal of nutrients. The most suitable forms of management on Celtic fields are extensive grassland or heath. Former arable can be sown with a grass mixture and grazed with sheep. Sheep (and to a lesser degree goats) do not trample the turf, and because of their specific grazing pattern and scattered droppings ruderal species will become less problematic than if cattle or horses are used. Tree growth and shrubs on the raised features should be avoided, for their roots can cause damage and shrubs will attract burrowing animals. However, it is important to consider carefully whether, and if so, how, vegetation control is necessary and whether it might have any negative side-effects. On non-loamy soils small sand drifts may form in places where the vegetation has been damaged. These can be covered with sods to restabilize the soil.

⁴⁸⁷ Van Doesburg & Stöver 2018.

⁴⁸⁸ Ibid.; Baas & Raap 2010, 3-185.

⁴⁸⁹ Postma 2010; Van Doesburg & Stöver 2018, 42.

⁴⁹⁰ Abrahamse 2000. A few terps have been covered with sludge dredged from the Reitdiep (terp Englum, 2002-2006) and Starkenborgh canals (terp Wierum, Adorp, 2006-2008), in response to subsidence on the terps.

6.15.5 Earthen banks, rural fortification systems, sconces

Earthen banks that are part of a national archaeological monument are constantly exposed to wind and water erosion, the actions of visitors, animal activities, or forms of maintenance (e.g. timber harvesting); see for instance Fig. 4.3 (Section 4.2.2). On this type of monument the basic conservation principle is to maintain the bank's existing height and, in the case of a scone or rural defensive system, also the depth of the ditch(es) so as to protect vulnerable archaeological layers. Examples of preventive measures are:⁴⁹¹

- Preventing damage by heavy equipment traffic, or designating one single thinning track where a bank may be accessed (e.g. by a harvester) to avoid damage to the entire bank;
- Maintaining sufficient distance during tillage activities (ploughing) on arable land bordering on banks (and ditches) (Fig. 6.4);
- Preventing soil disturbance by rooting wild boar by placing a wire mesh fence, or by culling (Section 6.13);
- Blocking recreational access or mountain biking by laying out guided recreational routes and offering mountain bikers attractive alternatives (Section 6.14).

Measures to repair damage and to mitigate causes:

- Removing trees and shrubs growing on the bank (however, see above, and also Section 6.12);
- Cutting back branches and crowns of trees growing on and near the bank;
- Maintaining dense foliage cover above the bank so as to prevent wildshoots/seedlings and to encourage a protective moss cover.
- Inserting a revetment into the bank (and the ditch) to conserve the original profile, for instance in places where a path or road cuts through the bank (Fig. 6.20)

6.15.6 Burial mounds and urnfields

Animals can damage burial mounds and urnfields by overgrazing with ensuing erosion, or by digging tunnels and holes.⁴⁹² Frequent traffic on burial mounds by for instance hikers, equestrians, or motor crossing is equally harmful, as are mountain biking or bicycle routes skirting past them. Other potentially harmful activities in relation to these vulnerable objects are forestry and agriculture as well as nature development and turf stripping.⁴⁹³ The vegetation which usually covers burial mounds and urnfields may include large trees; their roots threaten the soil archive, and in the event of a windfall a large section of the mound may be torn away. If the vegetation cover on a mound is too thin, erosion may occur.

Damaged sections can be repaired to prevent them from eroding further.⁴⁹⁴ Small defects in the body of the mound (<1m³), caused by rabbits or dogs, can be filled in, and placing wire mesh under the turf will prevent future digging. To keep wild animals (especially wild boar) away from burial mounds and urnfields some form of barrier can be erected, such as a fence.⁴⁹⁵ Mound sections that have disappeared can be restored. Reparation of defects larger than 1m³ is subject to a monument permit. Other possible measures to prevent root damage and windfall and to preserve the visibility (i.e. experience value) of a monument are mowing or cutting wildshoots and saplings (leaving the stubs behind).

Urnfield mounds, which are often barely visible, are smaller in circumference and height than 'ordinary' burial mounds and therefore even more vulnerable to turf stripping, scraping, roller chopping, ploughing and other activities in the context of forest and nature management (Section 5.5). Turf stripping, scraping, roller chopping, or tillage (e.g. ploughing) on archaeologically sensitive parts of the area should be avoided, for these activities truncate some of the micro-relief and render the surface (and possibly associated artefacts and features) susceptible to erosion and other forms of deterioration. Mowing is an acceptable alternative in these cases. When undesirable

⁴⁹¹ Baas & Raap 2006/2010, 3.139; Boosten, van Benthem, Jansen & Maes 2011. See also Jansen & Van Benthem 2005.

⁴⁹² Baas & Raap 2010, 3-85.

⁴⁹³ See e.g. Van der Heiden & Feiken 2018.

⁴⁹⁴ Baas & Raap 2006/2010, Chapter 3: *Cultuurhistorische beheermodellen*. The Cultural Heritage Agency of the Netherlands has published guidelines for the restoration and maintenance of burial mounds.

⁴⁹⁵ Dunwell & Trout 1999; English Heritage 2000.

tree growth is removed from an urnfield the stubs should be left standing; uprooting them would result in significant soil disturbance. Also heavy vehicle traffic will ultimately erase shallow urnfield features; it is crucial that this is avoided.

Mowing on and near an urnfield (or burial mound) should be done with light equipment: a brush cutter, or a two-wheel tractor with double tyres and boom mower unit.

Archaeological national monuments are sites which contain archaeological remains of such significance as sources of information about the past that they need to be preserved for future generations. The information contained in these sites informs us how people lived and buried their dead, how they traded, which objects they produced, how they waged war, and how and where they found their food. An archaeological national monument can also be a source of fascination or a commemorative place. Despite having survived in the soil for a long time, and also despite scheduling, the archaeological remains at these sites are subject to decay. These processes threaten the integrity of the monument and its features, and they also affect the preservation of various materials, such as flint, bone, metal, seeds, and ceramic objects.

Not every form of disturbance constitutes damage which needs to be prevented or stopped; there are different kinds of disturbance and varying degrees of severity. Damage can be local (e.g. windfall) or site-wide (e.g. soil erosion); some forms of damage happen suddenly (e.g. escarpment collapse) while others proceed very slowly (e.g. desiccation). Damage is defined as a situation in which the physical quality of archaeological remains on/in (a section of) a scheduled monument is decreasing. Damage can lead to a loss of information if information carriers (soil features, layers, objects) are no longer recognizable or if their meaning or mutual associations are lost, so that research questions at the level of the individual complex can no longer be answered. As such, information loss is a serious consequence of damage to the site. If information is (about to be) lost or expected to be lost in the foreseeable future, physical protective measures are necessary. If such measures are not possible, an alternative solution is a scientific excavation of the monument to preserve its information. However, the primary goal in the case of archaeological national monuments is long-term *in situ* conservation.

This report presents a review of the known physical threats which may cause serious damage to land-based archaeological national monuments. The report also presents recommendations as to what can be done to minimize or remove the risk of such threats. It is

important to be aware that current permit policies with regard to national monuments in themselves already prevent or mitigate some of the potential damage that might result from construction activities or deeper soil interventions, either by insisting that the project plans be adjusted or by denying permission altogether. However, these policies only go so far. They do not stop degradation by natural processes, when no individual can be held responsible. Moreover, except in the case of construction activities the effects of many soil interventions in (agricultural) rural areas are gradual and invisible, unknown to licencing bodies, and unsupervised.

7.1 Physical threats

7.1.1 In general

This report shows that four types of risk can be distinguished as regards the physical threat to archaeological national monuments:

1. Perceived physical threats that have turned out to be harmless. Among them are a number of processes and conditions which in the past were regarded as potentially dangerous to archaeological remains but which based on new information are now considered harmless. These include chemical processes such as manuring, soil acidification, salinization, and infiltration of oxygenated groundwater or rainwater in a saturated soil.
2. Threats which are no longer active, or only to a limited extent. This includes slow transformation processes which began when a site was abandoned by its residents/users and which continue to the present day. An example is bioturbation, the constant mixing of aerobe layers by soil organisms. Although bioturbation has been going on for hundreds and sometimes thousands of years, archaeological excavations are still unearthing remains and features below the surface. Processes like drainage, traffic, and tillage (by wild animals, livestock, horses, people and light

vehicles) have likewise existed for centuries and caused mild trampling, compaction and disturbance of the topsoil. Another physical threat in this category is the large-scale lowering of the (ground)water table carried out by water boards since the 1960s and 70s for the benefit of agriculture. In many cases the harmful effects of desiccation on non-carbonized organic remains have existed for decades, and the damage is already done. Due to the risks of salinization, desiccation, soil subsidence, and greenhouse gas emissions which are associated with a further lowering of the water table, this strategy is expected to be abandoned in the near future, or at least used sparingly. Whether the loss of information due to desiccation has come to a halt as a result is uncertain; in some cases conservation measures may still be advisable. An example is the archaeological scheduled monument at Aartswood, where there is uncertainty as to whether the organic remains in the deepest strata of the site are still intact.

3. Physical threats where a harmful effect is uncertain but suspected. An example are the reducing conditions and fading of soil features and stratigraphic layers ('blue-staining') which arise below an added soil layer or soil cover, and where it is uncertain whether these phenomena are reversible. Other examples are repeated ploughing/working of the cultivation layer, and harvesting. To what extent do these lead to soil displacement, a lowering of the surface, and the gradual truncation of archaeological levels directly beneath the plough zone?
4. Physical threats of which the harmful nature has been confirmed. This includes (un)intentional, harmful human interventions such as excavations and quarries, levelling, deep (agricultural) soil interventions, and many construction activities (Section 7.1.2). All these activities are subject to a permit. Natural processes such as soil erosion, animal burrowing, rampant tree or shrub vegetation, or the effects of drought can be considered harmful if they accelerate the deterioration of the entire complex. This is the only category of physical threat where it is necessary to assess whether (and in what

way) physical protective measures are feasible, or whether *ex situ* preservation (i.e. an archaeological excavation) is the only viable option.

7.1.2 Harmful processes and interventions

Harmful human interventions on archaeological national monuments include:

- Agricultural soil interventions leading to a (gradual) deterioration of archaeological levels;
- Activities in the context of construction, development, and infrastructural projects;
- Development and maintenance of (new) nature areas;
- Forestry;
- Water management (surface water and groundwater).

Harmful natural processes include:

- Deterioration of archaeological remains by slope erosion and field erosion;
- Increasing deterioration of national monuments by rampant vegetation and the burrowing of land-dwelling animals;
- Increasing deterioration of national monuments sensitive to desiccation due to precipitation shortages.

Agricultural usage

Many potentially disruptive activities in rural areas are associated with agriculture, such as decompaction, local field drainage, or levelling (Section 5.2 and 5.4). Physical soil interventions will destroy soil features and stratigraphy as well as associated artefacts and other remains. Annual primary tillage and harvesting may also slowly damage a monument. The gradual displacement of the cultivation layer by repeated ploughing, levelling, or decompaction will all result in a deeper plough soil, while repeated ploughing in slightly uneven areas may slowly erase local relief. As a result the upper archaeological levels may ultimately be completely absorbed in the cultivation layer. Any artefacts surviving in the plough soil will have lost their context and their association with

other artefacts and (likewise disturbed) features. Furthermore, such artefacts will be exposed to rapid decay due to mechanical and biological processes, which will affect their physical condition.

Activities in the context of construction, development, and infrastructural projects

Other important risks to archaeological remains proceed from construction and development activities (water, green zones, infrastructure). Throughout the building process (site preparation, construction), but also afterwards as the finished built environment is being developed, various activities take place which pose a threat to archaeological sites (Section 5.3). The construction of buildings and infrastructural elements (above ground and subsurface) is accompanied by digging to prepare the building site, for pavements, and for pipe and cable trenches. Landscape development is accompanied by newly dug canals and ditches and green elements, which may again lead to damage.

Soil removal physically disturbs a site, destroying features and stratigraphy and either displacing or destroying artefacts.

Foundation piles and sheet piling pierce archaeological layers and as such cause some degree of damage, while raising the surface can lead to distortion and compaction of soil layers and features.

Nature development and management

Examples of activities relating to (new) nature development and management which are harmful to archaeology are turf stripping and scraping, and to a lesser extent roller chopping and flail mowing on heathland that has been taken over by grass (Section 5.5). These activities can lower the relief on Celtic fields, urnfields, burial mounds, banks and cart tracks, disturb artefact scatters (displacement) and crush both artefacts and features (fragmentation).

Other harmful activities in the context of nature management are lowering the surface to create wetlands, and removing trees and shrubs including the root balls. Seemingly less invasive but still potentially harmful in the long term are maintenance-related activities such as pulling

wildshoots (manually or by machine), and machine mowing. (Heavy) machine traffic will compact the soil and cause rutting, while artefacts may be crushed and displaced and archaeological layers may be disturbed, although the severity of the damage is dependent upon soil humidity and local soil type.

Forestry

In a production forest with fast-growing tree species, stands are harvested and replanted by machines every 30 to 40 year. These activities may be accompanied by deep soil interventions (Section 5.5.2). Clearly they can cause damage to different types of archaeological objects, in the form of artefact fragmentation and piercing, disturbance of soil features, and levelling of archaeological micro-relief down to surface level. Traffic from (heavy) forestry equipment can likewise crush and displace artefacts and also disturb layers and features due to compaction and rutting. Again, the level of damage will depend on soil humidity and local soil type.

Water management

The purpose of water management is to achieve and maintain nominal water conditions in built-up and rural areas (Section 5.4). In built-up areas, a high groundwater table is undesirable as it would cause wet crawling spaces, flooded basements, and a reduced discharge capacity during peak rainfall. Agriculture too benefits from moderate to deep drainage as this greatly improves the soil's ability to tolerate heavy machine traffic. Large-scale infrastructural projects such as dike construction or relocation, the construction of large canals, and the reconstruction of natural watercourses can also have a profound impact on the groundwater situation. On a more modest scale, groundwater is constantly being extracted for industrial purposes, again lowering the groundwater table. Since the 1950s a combination of these factors has caused the Average Highest Groundwater level in much of the Netherlands to drop 20 to 40cm. Lowering the groundwater table – by means of active water management – can seriously affect non-carbonized organic remains (by creating aerobic conditions) and metal objects (by corrosion), in addition to leading to soil compaction.

Natural processes

Soil erosion is the most important of those natural processes that may be harmful to archaeological national monuments (Section 4.2.1). Particularly on fields with a $\geq 2\%$ slope, agricultural tillage can cause a net soil wash in which soil material and artefacts are moved downslope. The loss of soil also brings remaining archaeological remains slowly or rapidly within reach of the plough. As erosion progresses both these processes may ultimately destroy a site. On steeper slopes, saturated soil layers may even start to slide, a form of sudden or incidental erosion. When that happens, sites situated at the foot of the slope will be covered (and protected) by redeposited colluvium, as in the case of several Roman villa sites.

Plants and animals can also affect the soil archive (Sections 4.3 and 4.4). Examples include vast tunnel complexes on and near small archaeological monuments such as burial mounds, escarpments that are being undermined by burrowing animals, rooting through the slope profiles of visible archaeological landscape elements, or desiccation due to the presence of deeply rooted and rampant shrubbery.

Also to be mentioned here are the effects of climate change on soil humidity and groundwater levels. Precipitation shortages in spring and summer contribute to a reduced groundwater suppletion, a lower groundwater table, and a decrease in soil humidity. These processes affect soils which contain drought-sensitive archaeological remains at shallow depths.

7.2 The main risk factors

Studies in the Netherlands, the UK, Germany and Belgium indicate that the risk of irreparable damage to archaeological sites is most acute below arable fields and heathland, and in production forests. Together, the land use categories arable, grass, and nature cover nearly

81% of the total area currently occupied by national monuments. On January 1, 2018, arable fields covered more than 9% of the archaeological national monuments, grassland covered 37%, while more than 35% were subject to a nature management regime (Fig. 2.5). Especially visible and shallow sites with agricultural or nature-management regimes are at risk from gradual degradation processes.

Superficial soil interventions will not always damage the soil archive on an archaeological national monument. Guidelines have therefore been issued for most archaeological scheduled monuments to indicate which interventions can be carried out without a permit. However, many soil interventions in agricultural areas (with the exception of construction activities) and in nature areas which exceed the maximum exempt depth are nonetheless carried out without a (monument) permit. Virtually all permit applications in agricultural areas concern construction activities, which means that these forms of degradation can continue unbeknownst to the licencing body, and without regular supervision.

The same problems relating to the gradual degradation of vulnerable archaeological heritage apply to water-table management in rural and urban areas. Lowering the surface water table by pumping or groundwater extraction are not subject to a permit, because these activities are carried out outside the boundaries of the archaeological national monument.

The increasingly urban environment in which archaeological national monuments are situated is also a source of potentially disruptive activities. These usually relate to construction activities and infrastructural projects above and below ground. If scheduled archaeological monuments are involved, many of these activities are subject to a permit so that measures can be taken to limit or prevent damage.

7.3 Main risk factors in relation to monument type

The risk of damage to the soil archive by soil interventions or atmospheric phenomena (erosion, aerobic processes) is much greater for shallow subsurface sites and visible archaeological remains (e.g. terps, burial mounds) than for covered sites and those at greater depths. Visible monuments make up nearly 55% (4,062ha) of the total surface of all archaeological scheduled monuments combined. In addition, more than 38% of the total surface (2,845ha) contains archaeological remains at a depth of less than 50cm -GL. These two monument categories are particularly exposed to or susceptible to physical threats, and together they also form the largest group (both in surface and in number) of scheduled archaeological sites in the Netherlands.

The risk of damage to the appearance of visible archaeological national monuments is considered to be much smaller than that of damage to invisible monuments below arable, also because the degradation of the latter is often gradual. Of the visible archaeological national monuments, more than 5% is taken up (in part) by arable (205ha) while 22% is being managed as (agricultural) grassland (895ha); most of the latter are terps in the north of the Netherlands. 63% of all visible archaeological national monuments are being managed as nature areas (woodland, heath, sand drifts). The remaining 10% are taken up by built-up areas, roads and paths.

Of the total area occupied by archaeological national monuments with shallow subsurface archaeological remains, 42% has an agricultural function (1,427ha), 49% is being managed as a nature area (1,680ha) and 9% is occupied by buildings, roads or paths. The risk of gradual damage is particularly high for sites with shallow subsurface archaeological remains.

7.4 Halting or preventing damage

7.4.1 Agricultural and nature management and forestry

Various alternatives to regular agricultural tillage have been developed to enable more archaeology-friendly forms of agricultural usage. These alternative techniques are often grouped under the catch-all term 'non-reversal tillage'. Non-reversal tillage ranges from a complete halt of all forms of tillage ('no tillage') to switching to minimally invasive techniques. Allowing fields on and around a vulnerable section of the monument to lie fallow or switching to extensive grassland management are equally archaeology-friendly methods. Modified agricultural usage and specific techniques such as wetland cultivation in peat meadow areas can also contribute to the conservation of (in this case) archaeological remains that are susceptible to desiccation damage.

A possible measure in forestry is clearly marking archaeologically sensitive areas with a fence or barricade tape. For timber planting and harvesting it is recommended to use fixed thinning and dragging tracks. On sandy soils it is advisable to harvest timber in damp conditions; on loam and clay soils, dry conditions are best. After felling it is important not to dig out the roots.

In nature areas, grazing and burning are the preferred methods to reduce the soil nutrient content and to control wildshoots. However, it is not enough to select the right technique to limit potential damage. It is also important to be clear as to how the commissioning and executing bodies define the terms 'mineral soil' and 'humus layer'. This varies from person to person, with one individual referring to organic matter lying loose on the surface while another takes these terms to refer to the upper layers of the original podzol.

Furthermore, all sectors (infrastructure, construction, and agriculture) are advised to use machines and vehicles with a low axle pressure so as to minimize rutting and soil compaction and thus to reduce the risk for archaeological remains.

7.4.2 Construction and development activities

Construction and development activities happen everywhere, both in urban and in rural areas. As commissioning body, the Cultural Heritage Agency of the Netherlands is very reluctant with regard to allowing harmful spatial development-related activities on archaeological national monuments. Heritage value takes priority, and if disturbance is unavoidable strict conditions are posed upon the project plan. If this is not feasible (or only to a limited extent), subsequent archaeological research has to meet strict criteria. Both plan adjustment and archaeological research should be case-specific, depending on site type, local soil conditions, and the nature of the planned construction.

7.4.3 (Ground)water management

Physical measures to minimize the risk of desiccation and erosion primarily aim to restore or raise soil humidity in the affected areas. Establishing a local nominal (surface) water level around a site is only useful if this actually improves preservation conditions by maintaining a high soil water content and low oxygen content in the area. Occasionally the correlation between surface and groundwater levels and soil water content can be weak or variable, and the practical feasibility of raising the level can be limited. *In situations* where this is nonetheless efficient and desirable, the (local) surface water level can be controlled by placing small culverts, constructing retention dams around the site, or using (inundation) screens. Another option is diverting water to the site to achieve a satisfactory level. These techniques can also be used when the surface level in the areas surrounding the monument is (naturally or

artificially) below that of the monument itself. Raising the water level can be done locally or across a much wider area.

Besides adjusting the water level another option is to influence soil capillary action (groundwater percolating upwards through the soil particles) by applying extra layers of soil to the site. Groundwater evaporation can be reduced by covering the site with non-permeable soil or geo-textile. A grass cover that is kept short and therefore has short roots also helps to maintain soil humidity by reducing evaporation.

7.5 Knowledge gaps

7.5.1 Agricultural usage and nature management

In recent years several studies in the Netherlands and abroad have assessed the effects of agricultural practices on archaeological remains, and potential physical measures to prevent damage. However, these studies largely concentrated on the mechanical impact of tillage, strain, and soil compaction on shallow subsurface archaeological remains. Other, more gradual forms of degradation caused by agricultural practices received less attention, such as the piecemeal truncation of buried archaeological sites in level areas as a result of topsoil displacement (by e.g. levelling, ploughing, cultivation), turf stripping, or roller chopping in nature areas. Because of the shallow position in the soil of many buried archaeological remains, the potential impact of this process of gradual truncation is significant. Moreover, greenhouse cultivation may perhaps have an effect on soil humidity and on oxidation and reduction processes. The following questions still need to be answered:

- Under what conditions can repeated turning, mixing, de-compacting and levelling of the cultivation layer result in a piecemeal truncation of the underlying archaeological levels? At what rate does this happen, and what alternative tillage methods or physical measures can be taken to prevent it?

- What is the effect of cultivation in green-houses without a hard floor surface on soil humidity and groundwater levels under the greenhouse? Does desiccation proceed more quickly inside a greenhouse than outside, in the open air (no rain inside a greenhouse while evaporation continues)? What are the consequences for metals and non-carbonized organic remains?
- In which soil types and under which conditions will features begin to fade due to ‘blue-staining’?
- What is the minimum size (if any) of the area covered by an added soil layer or hard surface for blue-staining to occur?
- Is blue-staining reversible or irreversible? And if reversible, when will soil features be recognizable again?

7.5.2 The built environment

In recent years the effects of different construction techniques and practices and of the various forms of ‘archaeology-friendly’ construction on the archaeological soil archive have received much attention (Section 6.7). Yet some questions still remain as to the (potentially) harmful impact of different construction techniques:

- What is the impact of high-pressure grouting and injection of liquid concrete, (expanding) resins, or silica gel on a soil containing anthropogenic layers?
- What is the impact of soil compartmentalization on a built-up site on the archaeological soil archive?
- What is the impact of removing sheet piling and foundation piles by means of vibrating or pulling on archaeological remains?

Furthermore, several situations are known to result in the erasure or fading of soil features, and there are indications that a relation exists between these processes and changes in the soil redox situation, the presence of organic matter, and certain iron compounds. Degradation of soil features on for example sandy soils has actually been observed (e.g. the ‘bleaching’ of features on the sandy soils of the province of Noord-Brabant), but so far few studies have looked at these processes and their harmful effects. The most important issue with regard to soil features is under which conditions they will (continue to) be visible:

- What are the effects of changing soil conditions (water content, leaching) on the visibility of features?

7.5.3 Water management

Raising the groundwater level and manipulating soil humidity around archaeological remains susceptible to aerobic degradation can both be deployed as physical protective measures. Examples are clamping wrecks on dry land, manipulating nominal surface water levels, taking measures to facilitate infiltration, and constructing retention dams. When many of these measures were introduced no data were collected as to their specific effect on the soil water content around archaeological remains. In view of the fact that raising groundwater levels and manipulating soil humidity are frequently used for protective purposes, more data are needed on the preservative effects of groundwater and groundwater systems.

- What is the nature of the relation between groundwater and surface water levels and the preservative capacity of the capillary zone and of pendular water?
- How long is the interval between a drop in surface water level and the onset of aerobic conditions? Which factors play a role in that process?
- How long is the minimum interval between a (temporary) drop in the water table and the onset of desiccation and other harmful effects on archaeological remains (metal, organic remains)? Which factors play a role in that process?
- Is there any information on the degradation rate of non-carbonized vegetable and animal materials upon being exposed to desiccation?
- What is the effect of the factors soil texture (sand, clay, loess) and soil usage (arable, grass, nature) on this rate?

- Which factors are responsible for the observed variation in the preservation and the degradation rate of different types of vegetable remains (e.g. wood, seeds, fibre)?

7.5.4 Root action

The extent of damage to archaeological remains by root action is not always clear and in most cases invisible. Many archaeological trenches in the Netherlands show the telltale signs of centuries of root action but nonetheless still contain legible features and identifiable artefact scatters. This may give the impression that the damage to archaeological remains by vegetation is limited. However, rapid or sudden root action can definitely affect (and in some cases cause damage to) the archaeological soil archive. Examples of rapid deterioration are isolated cases of windfall, the presence of invasive, deep-rooting plant species, or root pressure on structures or layers.

Several questions still remain unanswered:

- Which plant species relevant to the Dutch situation have long, penetrating root systems, how deep do these reach, and what is the potential nature of the information loss?
- What is the effect of tree roots on soil humidity and archaeological remains?
- Which physical measures will best prevent rampant growth of trees, shrubs, helophytes, fast-growing deep-rooting species, and other prolific plants? Under what conditions are these measures most effective, when are they ineffective, and when are they counterproductive?

7.6 Final remarks

The Netherlands possess a rich archaeological soil archive, which is often the only source of information on the long history of the country and its inhabitants. Some of this archaeological heritage is visible: megaliths, terps, burial mounds, mottes, or castle ruins. And although by no means all visible archaeological sites are also national monuments, many of them are. A smaller proportion of the archaeological national monuments are invisible, and their presence is almost intangible. Their significance and value are first revealed during scientific research and the narrative created by it.

The goal of the protection of both kinds of archaeological monuments, visible and invisible, is the preservation of archaeological remains as sources of information about the past. The chosen strategy to achieve that is *in situ* preservation. However, the subsoil is not the only medium containing a wealth of archaeological information. Visible national monuments such as megaliths, terps, and burial mounds are equally important carriers of cultural historical identity. The terps, for example, are important visual landmarks in the northern Dutch coastal areas and part of the regional identity.

Especially the protection of the visible national monuments is undisputed in wider society. Nonetheless a conflict occasionally arises between the public interest and the interests of a landowner/user. Whereas owners of scheduled buildings at least derive some pleasure from their property the owners/users of

an archaeological national monument as a rule gain nothing from the protected status. On the contrary, that status often curtails their options to make use of their property and blocks new development of the site or makes it very expensive. Effective archaeological national monument conservation is possible only if the various interests and risks are balanced and if an effort is made to ensure that conservation measures are appropriate. It is also important that adequate information is available on the information value and vulnerability of the archaeological remains, so that negative effects of land use and maintenance can be minimized while maximizing the positive effects.

Structural and regular monitoring of the national monuments' physical quality enables the Minister (who having scheduled the monument is also the responsible authority) to decide upon conservation measures to preserve a national monument if its physical condition has greatly deteriorated or is deteriorating. If physical protection is impossible, archaeological excavation of (parts of) the monument is the final option. In addition to monitoring the national monuments' physical state it is also necessary to constantly evaluate and update our current information on factors that might be detrimental to archaeological remains.

If development of the site of a national monument is inevitable, the permit applicant can be ordered to thoroughly explore all options for an archaeology-friendly alternative solution. However, not all interventions on archaeological national monuments are subject to a permit, and even when they are a permit application is not always filed. It is for this reason that the importance of adequate public information to motivate and raise more understanding and support for conservation policies can hardly be emphasized enough. Few caretakers, whether they are farmers, builders, or administrators, are familiar with the fragile nature of archaeological heritage.

What matters most is that the conservation of archaeological national monuments requires that all parties reach a mutual understanding of each other's wishes, demands and standpoints so that all feel a shared responsibility to preserve this national heritage. The present publication aims to contribute to this sharing of knowledge and the fostering of a better understanding.

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Except when stated otherwise the following definitions and explanations have been provided by the Cultural Heritage Agency of the Netherlands. As they are intended only as guidelines, references to standard sources have been omitted.

(An)aerobic

In the presence/absence of air (oxygen).

(Archaeological) soil archive

Those sections of the subsoil in which traces (objects, soil features, deposits) of human settlement and human environmental impact (such as ecological remains or sediments) have been preserved. Conditions favourable to (meta-)stable preservation are not limited to deeper layers; plough soils or shallow urban soils also become part of the soil archive due to the archaeological material circulating in them.

(Archaeological) monitoring

Assessing and observing the physical condition of a monument with reference to a series of specified parameters during a specific period and using appropriate instruments, for the purpose of collecting information on the physical degradation processes affecting the archaeological monument and on the effectiveness of measures to mitigate the effects.

(Archaeological) site

See archaeological monument.

Deterioration (qualitative or informative)

See degradation.

Discharge

The outflow of water via a system of water courses towards one of a drainage area's discharge points.

AMK area (AMK = Archaeological Monument Map)

An archaeological monument eligible for preservation that is recorded on an archaeological policy map and is subject (usually) to protection in the context of a zoning regulation.

Inorganic remains

Archaeological remains composed of inorganic materials such as metal, stone or pottery.

Anthropogenic

Made by humans or affected by human action.

Aquifer

A (series of) water-bearing, permeable soil layer(s).

Archaeological monument

Area which constitutes cultural heritage due to the presence of, and including, physical remains, objects, or other traces of human presence in the past.

Archaeological national monument

An archaeological monument listed in the Dutch National Monuments Record, the rijksmonumentenregister.

Threat (level of)

The Protocol Archeologische Monitor (landbodems), Version 4.7, distinguishes several categories of visible endangerment, ranging from 'hardly to none' and 'moderate' to 'immediate'. See also Section 6.2.

Threat (type of)

Any intervention or natural process which poses a potential threat to the archaeological remains contained in (a section of) a national monument and as such may cause damage to it.

Maintenance

The implementation of a regular maintenance regime in the form of a set of measures to restore and safeguard the condition of an archaeological monument. The goal of a maintenance regime in this sense is to preserve the monument's information value and/or its experience value.

Preservation measure

Any measure intended to ensure the *in situ* preservation of an archaeological monument's information or experience value. However, information value can also be preserved *ex situ*.

Experience value

The degree to which an archaeological site is appreciated for its aesthetic or commemorative aspects.

Biocide

Any blend of one or several active ingredients intended or deployed to destroy, deter, render harmless or in other ways chemically or biologically control a noxious organism, or to prevent its undesirable impact, and which is not an herbicide (2007 Herbicide and Biocide Act).

Bioturbation

Processes in which the soil is physically turned over, disturbed or dug through by animals or plants. Bioturbation includes the ingestion and excretion of soil particles by soil organisms (earthworms) as well as the formation of animal burrows (moles) and root systems in the sediment.

Site compartmentalization

A landscape process whereby soils that are part of a formerly contiguous archaeological site are fragmented through time into smaller sections (compartments), as a result of large-scale building projects of high intensity and density, the construction of traffic infrastructure (roads, railways, waterways), agricultural parcellation (ditches), or the installation of underground services. These processes may have a physical impact on archaeological sites due to their potential effect on (soil) drainage and on the integrity of the stratigraphy.

Soil environment

Conditions in the soil which affect the physical state of (archaeological) materials and substances contained in that soil.

Soil variation

Spatial variations in aspects of the soil, such as particle size distribution, humous content, moisture, mineral components, and soil biology.

Soil humidity

Water retained in the unsaturated section of the soil.

Building

Any construction in timber, stone, metal or other material, regardless of size, which at its intended location is connected (directly or indirectly) to the surface or supported (directly or indirectly) by or below the surface, and which is intended to function at that location ('building' as defined in Section 1.1, Paragraph 1, of the Modelbouwverordening (Standard Building Code) VNG 1992). Examples are residential buildings, office buildings, transformer cabinets, windmills, bridges, pumping stations, and other man-made constructions. Buildings occur in both urban and non-urban areas (rural areas).

Capillary fringe

The subsurface layer in which groundwater seeps up from a water table by capillary action to fill the pores.

'Chopping'

Mechanical removal of vegetation and part of the upper humus layer (down to a depth of 4cm), which remains partly intact. The removed material is immediately disposed of. Chopping is more invasive than mowing but less invasive than complete stripping of the turf.

Complex

A cluster of objects and/or features that are spatially and chronologically associated.

Complex type

Interpretation of a specific (cluster of) object(s) and/or feature(s); an indication of the system/context in which an object or feature originally functioned.

Conservation

Measures to minimize the natural decay of an object and/or its surroundings, based on the principle of maximum reversibility.

Consolidation

1. Taking measures with regard to a site's layout, development and/or maintenance so as to slow down degradation as much as possible; 2. The result of such measures.

Cultivator

Mechanical tillage device with teeth/tines, used to loosen (but not turn) the soil at variable depths. For superficial action, see below (seedbed cultivator-harrow). Cultivators with fixed teeth or shanks and a deeper impact (also known as a chisel plough or subsoiler) are used to break up compacted layers. If this compacted layer is a plough pan (see below) the depth will be limited to 20 to 40cm.

Cultural layers

In the Netherlands, cultural layers, also known as archaeological layers, occur particularly in settlement areas on Holocene soils. Cultural layers are formed when settlement debris (pottery, wood or other organic materials, burnt or unburnt) is mixed with the substrate below the original surface. Archaeological features tend to be well preserved under cultural layers. In a core sample a cultural layer is visible as a humic section containing charcoal particles.

Degradation

(Decay, deterioration). A process in which the quality of objects or features is negatively affected by changes in the physical, biological and/or chemical environment.

Reversal plough

Heavy-duty plough which reaches below the plough soil. The obtained depth depends on local conditions (for instance the wishes of the user of the land, or the depth of undesirable layers) but in exceptional cases may be up to 2m.

Diepspitten ('deep digging')

Turning over the soil to a great depth using a spade. Extensive stretches of heathland were reclaimed in this manner in the Netherlands in the 1930s as part of various unemployment schemes. Many fields in the province of Brabant were also worked in this manner so as to preserve soil fertility.

Chisel plough

(subsoiler) See cultivator.

Differential load

Variations in pressure at different soil levels as a result of an overlaying soil package of variable thickness or weight.

Dozer

Among professionals, another word for bulldozer.

Drainage

Artificially induced discharge of groundwater via drains and/or surface water.

Stage

The difference in elevation between the ground surface and the nominal water table in a (natural or artificial) watercourse.

Dynamic water table management

Dynamic water table management involves an ongoing anticipation of and response to actual and expected weather conditions, so as to be able to reduce the built-in extra safety margins inherent in static water table management. The main purpose of dynamic water table management is to maximize the water system's (surplus) retention capacity. As such, this type of management contributes to a greater safety. Based on expected levels of precipitation the water table at a pumping station is lowered to a specified minimum level without letting the ditches fall dry. When a dry period is predicted, the water table is raised or supplemented to a specified maximum.

Harrow

A harrow is a frame of wood (in the past) or metal (today) into which multiple short tines (ca. 7cm) have been inserted. When the harrow is pulled across the surface, these create shallow furrows which rarely reach below the plough soil. A harrow is used to prepare the field for sowing.

Owner

A natural or legal person who has legal ownership or other legal claims to an archaeological monument.

Leasehold

In the Netherlands, a form of lease in which the leaseholder purchases the right to use immovable property (land) owned by another for a given length of time, typically 49 or 99 years, and treat it as if he were the owner, including the right to build on it or sell the leasehold to others.

Lease holder, lessee

A person who owns immovable property (land) in leasehold

Lessor, landlord

A person who gives immovable property (land) in leasehold to a lessee.

Erosion

Collective term for processes which detach and transport soil material. Examples of erosive agents are wind, ice, or running water.

Evaporation

Evaporation may involve soil moisture as well as precipitation intercepted by vegetation.

Evapotranspiration

The cumulative sum of evaporation and transpiration.

Freatic zone (= groundwater level)

The level at which the water table stabilizes in a bore hole.

Freatic plane (= groundwater table)

Imaginary plane through the groundwater level at all points in an area where the level is dependent solely on the water column's hydraulic head.

Freatic groundwater

Free groundwater whereby the hydraulic head is dependent exclusively on the height of the water column. The upper boundary of freatic groundwater in a permeable layer above a poorly permeable or impermeable top layer is the freatic plane.

Rotary cultivator

Non-reversal tillage tool. A rotary cultivator does not turn the soil, like a plough, but homogenizes it.

Physical protection

1. The implementation of measures intended to secure the *in situ* preservation of archaeological monuments as sources of information and experience. 2. The outcome of such measures.

Physical measures

Concrete measures taken by land owners/land users on their property to prevent or halt damage to archaeological remains. Such measures may be taken once in the context of the layout and development of the site, or be part of a regular maintenance regime (see maintenance).

Average Highest Groundwater level (HGW; in Dutch Gemiddeld Hoogste Grondwater, or GHG)

Average of all levels for HG3 measured over a period of at least eight consecutive years during which no interventions have taken place.

Average Lowest Groundwater level (LGW; in Dutch Gemiddeld Laagste Grondwater, or GLG)

Average of all levels for LG3 measured over a period of at least eight consecutive years during which no interventions have taken place.

Pesticide

Mixture containing one or more active ingredients which are used to protect vegetation or vegetable matter from various noxious organisms or to prevent the effects of such organisms; to influence biological processes of vegetation other than those relating to nutrition; to preserve vegetable matter; to kill undesirable types of vegetation; to destroy parts of plants or slow down or prevent undesirable plant growth. See also Biocide (Wet Gewasbeschermingsmiddelen en Biociden [Plant Protection Products and Biocides Act] 2007).

Land user

A person who is entitled to use a plot of land but is not necessarily also its owner.

Groundwater

Water below the surface and the groundwater table.

Groundwater table

See Freatic plane.

Groundwater level

See Freatic zone.

Groundwater stage

Classification of average groundwater levels relative to the surface, measured over a period of several years. Each level in this classification represents a specific subsurface segment of the entire trajectory of the average highest and lowest groundwater table, expressed as the arithmetic average of respectively the top three (HG3) and bottom three (LG3) groundwater tables per hydrological year (1 April – 31 March) measured during a period of at least eight consecutive years. See also Table 3.1.

Pendular water

Water retained in the pores of the upper soil layers which is not in contact with groundwater. Pendular water may be the result of temporary high groundwater levels, but usually it is caused by rainfall.

Commemorative value

The reminiscences of the past evoked by an archaeological monument.

HG₃

Average of the three highest groundwater tables measured during a hydrological year, measured at bi-weekly intervals.

Hydrology

Science studying the presence, movement and composition of water on and below the land surface (MER).

Hydrological year

A hydrological year runs from 1 April to 31 March.

Conservation

1. Measures intended to ensure the *in situ* preservation of the information value and/or experience value of an archaeological monument. 2. The outcome of such measures.

Loss of information

The loss of archaeological information when the recognizability, significance, or association of features, objects and layers (information carriers) in the soil are lost so that certain aspects of the past can no longer be retrieved. Local/limited threats and forms of damage do not always lead to information loss but can do so.

Information value

The significance of an archaeological monument as a source of information about the past. The information value depends on the extent to which an investigation of the archaeological monument may produce new knowledge about the past.

Site development

Laying out and developing an archaeological monument in such a way that a (further) loss of its information value is prevented or its experience value is improved or restored.

Site development measures

Measures taken to ensure the above.

Instrument

A tool to achieve a specific goal or set of goals.

Integral water management

A set of coherent policies and management regimes by the various government bodies that are involved in water management strategy and management from a hydrological systems perspective. Integral water management takes into account internal functional relations (between the qualitative and quantitative aspects of surface and groundwater) as well as external functional relations (between water management and other policy fields such as the environment, spatial planning, and nature conservation).

Interception

Precipitation which clings to vegetation and/or objects as a water film or in the form of droplets.

Infiltration

The downward movement of precipitation into the soil.

Kilveren

Using a tractor with attached angle blade to scrape off and redeposit thin layers of soil in order to level an area. Electronic equipment often allows a precision down to a few centimetres. Levelling may completely destroy the historically formed relief in an area.

‘Flailing’/flail mowers

In this procedure a flail mower – a powered tool equipped with a set of flails attached to a rotating steel drum – is used to beat down and chop the vegetation rather than cutting it at ground level. The resulting mulch is left on the surface to add new nutrients to the soil, and also to prevent remaining seeds from germinating. Flail mowers can cope with tall vegetation and obstacles such as branches or waste.

Consolidation

Consolidation is the process whereby the soil decreases in volume as it settles and becomes denser, with a lowering of the surface level as a result. Consolidation occurs when formerly submerged sediments fall dry. While still submerged the soil particles display little or no cohesion, in part due to saturation. Once dry, however, the sediment loses its water which leads to a decrease in volume and an increase in particle cohesion (settling). The degree of cohesion depends on the type of soil: little or none in sand, but extensive in clay or peat. While settling in itself also leads to a drop in surface level, the terms consolidation and settling are often used together although in fact they represent two distinct processes. In theory, consolidation and settling both continue forever although in time the rate will slow down to almost zero. For practical purposes consolidation is therefore assumed to have stopped after a century, and settling after thirty years.

Kluitenbak ('clod bucket')

Jib and bucket on a mechanical digger with which trees can be removed with the root system intact.

Shrinkage

A drop in the surface level as a result of desiccation. See also settling, compaction, and consolidation.

Seepage

Vertical upward movement of groundwater towards the surface via drains, springs, or capillary action.

Agriculture

Agricultural legislation defines agriculture as those activities which constitute arable farming, pasture, animal husbandry, poultry farming, horticulture, osier and reed farming, and any other type of cultivation. A number of law sections also apply to forestry.

LG3

The average of the three lowest groundwater tables measured at bi-weekly intervals in the course of a hydrological year.

Measure

Action or intervention to achieve a certain goal or goals.

Deep tillage

Mixing several soil layers by reversing the entire soil profile in one go, using a reversal plough mounted with one or more curved shanks with replaceable tips.

Mengrotor

Mechanical appliance with a rotor blade, used to coarsely mix the soil down to a level of 80-125cm. This usually results in a lumpy structure in which the original layers can still be recognized. In the past, mengrotoren were used primarily in the reclamation of the IJsselmeer polders and the eastern Dutch peat marshes. Today they are still used occasionally to counteract soil compaction.

Flat lifter

Agricultural mechanical tillage tool with one or more heavy shanks, used to loosen and mix the subsoil and plough soil down to a greater depth.

Metastable

A dynamic system is said to be in a metastable state when a relatively minor change in its conditions would cause a major disruption.

Mineralization

Process in which organic components (derived from fallen leaves or other vegetable material, or animal remains) in the soil or on the surface are converted by micro-organisms into inorganic (mineral) components (nitrate, carbon dioxide).

Mitigation

Limiting or counteracting the impact of interventions or processes.

Monitoring

To keep under observation for the purpose of regulation or control.

Monument

Any built and designed monument, regardless of its protected status.

Natural degradation

Qualitative decay of materials or subsoil features caused by changes in physical and/or chemical environmental factors which are the result of natural processes or human activity in the distant past.

NEBO50

National soil map of the Netherlands, scale 1:50,000 (current version PEDOK).

Net precipitation

(= useful precipitation, = natural groundwater suppletion) The difference between precipitation (minus interception) and evapotranspiration. If evapotranspiration exceeds precipitation, the difference is known as precipitation deficit.

Non-reversal tillage

In non-reversal tillage the soil is not ploughed over but merely loosened to counteract compaction and erosion, and also (if done properly) to prevent further disturbance of the layers below the plough soil. In the Netherlands, non-reversal tillage is a relatively recent phenomenon.

Non-destructive research

Research at an archaeological site that causes only minimal damage, such as coring to obtain soil samples for micromorphological analysis.

Subsoiler

A tractor plough-mounted extension consisting of three or more heavy vertical shanks (standards) mounted on a toolbar or frame and used to disrupt the plough pan below the plough soil. A chisel plough with only one shank is also known as a subsoiler; it can reach much deeper than the plough-mounted type.

Drainage

Diverting surface and subsurface water in a particular area towards a larger water system by means of for example underground drains or ditches.

Vadose zone

The undersaturated portion of the subsurface that lies above the groundwater table. The soil in the vadose zone is not fully saturated with water; the pores within them contain air as well as water.

Oxidation-reduction boundary

Level relative to Amsterdam Ordnance Datum at which the oxidation-reduction zone becomes a reduction zone. Below this level, no oxygen has penetrated the soil. Above it, oxidation is manifest in the presence of orange/brown oxidation stains in the sediment. No oxidation phenomena occur in the reduction zone, although sulphide ore, pyrite, vivianite, and fougèrite may be encountered.

Lease

A legal contract which gives the lessee certain use rights to immovable property (land) owned by another person in return for a fee, for the duration of the lease.

Lessee

Person leasing immovable property (land) owned by another person.

PDOK

Abbreviation for the Dutch digital platform Publieke Dienstverlening Op de Kaart. PDOK aims to make geodata generated by Dutch government bodies publicly accessible (www.pdok.nl).

Peilbesluit (ca. 'water table policy document')

Formal document issued by (a) local waterboard(s) and the provincial administration which lists the nominal water tables in the area.

Peilvak (ca. reservoir)

Area within which the same water table is maintained throughout. Also called peilgebieden in the second Water Management Plan of the Hydrological Research Committee (Commissie voor Hydrologisch Onderzoek).

pH

(acidity/alkalinity)

Unit indicating the acidity or alkalinity of a water-based solution. $\text{pH} < 7$ = acid, $\text{pH} > 7$ = alkaline, $\text{pH} = 7$ = neutral.

Plough pan

Compacted layer below the plough zone which may form when the same plough depth is adhered to over a longer period. The presence of plough pan has a negative impact on crop development. Plough pan is usually disrupted every few years by means of a cultivator, subsoiler or chisel plough.

Redox potential (Eh)

A measure of the tendency of a substance of chemically identical molecules to acquire electrons from or lose electrons to an electrode and thereby be reduced or oxidised respectively. In the context of this report, a measure of the tendency of groundwater to oxidize materials, for instance organic matter.

Redox reaction

Chemical reaction in which electrons are transferred between two or more substances. The substance to which the electron is added is said to have been reduced; the substance from which the electron is removed is said to have been oxidized.

Restoration

1. All interventions relating to a damaged or partly obliterated building, archaeological relic or object which are carried out for the purpose of restoring them to a specified state; 2. The outcome of such interventions.

Remaining value

See information value

Retention

Delay in the mass transport of substances in the soil relative to the flow rate of water.

National monument (Rijksmonument)

A built monument or archaeological monument listed in the Dutch National Monuments Record, the rijksmonumentenregister. An archaeological national monument may comprise several AMK areas (see above, AMK).

Ripening

The settling of soils is closely associated with ripening. The term settling refers to the decrease in volume, or the resulting drop in ground level, which is caused by ripening processes. Ripening can take several forms: physical (whereby the interstitial water molecules between the soil particles are released); chemical (conversions due to exposure to air, which will also release interstitial water; but also oxidation of organic materials, which in peat soils will lead to an extreme reduction in volume); and biological (processes resulting from the presence of biological organisms in the soil, bioturbation, or the absorption of water by vegetation).

Damage

Deterioration of the physical qualities (integrity, conservation) of archaeological remains in (a part of) a national monument. Damage may lead to a loss of information.

Aesthetic value

The aesthetic-landscape value of an archaeological monument, especially those expressed in the monument's visible features.

Inspection

Assessments, visual or by means of simple instruments, of the condition of an archaeological monument, carried out at regular intervals.

Spader

Two types are currently in use: 1. Crankshaft spader. Incidental reversal tillage and homogenization; the spading motion breaks up the soil, typically down to 25-30cm below the plough soil, as an alternative to ploughing, 2. Rotating spader/cultivator. Incidental semi-reversal tillage and homogenization by means of rotating hoe blades but without spading; an alternative to ploughing, typically not beyond the plough soil.

Hydraulic head

The level to which a column of water will rise in a piezometer (a measuring device). In a freatic plane, the hydraulic head equals the groundwater table.

Nominal level

The desired surface water level in a specified situation.

Drainage basin

Contiguous areas which discharge into the same body of surface water.

Sulphide content (archaeological levels)

The presence of sulphides in the soil at levels where features and/or objects that are part of the archaeological complex can be expected to be present. The presence of sulphides can be ascertained by smell ('rotten eggs'), and below the redox boundary by chemical testing, using a 10% solution of hydrochloric acid (HCl).

Sulphide boundary

Maximum depth in metres below Amsterdam Ordnance Datum at which the soil still contains sulphides. The boundary can be established by smell ('rotten eggs'), and below the redox boundary by chemical testing using a 10% solution of hydrochloric acid (HCl).

Taphonomy

Study of the chemical, physical and biological processes involved in the putrefaction, decay and alteration of a dead organism under different conditions following burial. In general, the study of all organic remains under these conditions.

Taxon

(Plural: taxa) A group of one or more populations of an organism or organisms designated as a unit by taxonomists, such as a family or a species. Taxa are usually named.

Cultivation layer

Top 10-15cm of the plough zone, in which plant roots are concentrated. Cultivation layers are usually intensively worked and completely homogenized.

Transpiration

Evaporation of moisture from living organisms.

Seedbed cultivator-harrow

Type of spring-tooth cultivator, which typically does not penetrate beyond the cultivation layer.

Horticulture

The commercial cultivation of vegetables, mushrooms, fruit, flowers and other plants, trees, flower bulbs, or seeds, both in greenhouses and in the open field.

Desiccation (natural)

All unintentional effects of a drop in the groundwater table and the ensuing water shortages, mineral deficiencies, and changes in seepage and precipitation on woodland and other nature areas and on the landscape. Nature areas are also considered to be desiccated if an extremely low groundwater table necessitates the import of low-quality water from elsewhere. Drought mitigation measures are intended to counteract these negative effects.

Fragmentation (of a site).

A landscape process whereby formerly contiguous archaeological areas or cultural-historical features through time become fragmented into smaller units, as a result of large-scale building projects of high intensity and density. In addition to the physical effects on archaeological sites, fragmentation may also have legal consequences, especially when the resulting smaller units also have different owners. See also Compartmentalization.

Intrusive vegetation

Vegetation (trees, shrubs, and halophyte species such as reed) with root systems which will disturb or have already disturbed the underlying archaeology as they penetrate deeper into the soil.

Visual inspection

Het visueel, dan wel met eenvoudige hulpmiddelen, waarnemen van de conditie van een archaeological monument.

Capillary zone

Soil layer directly above the groundwater table in which virtually all pores are filled with water due to capillary action.

Water balance

An indicator, calculated by a standard equation, of the total volume of water inflow, outflow, extraction, and retention fluctuations during a specific period within a specific area.

Water conservation

Limiting or preventing water outflow so as to prevent or mitigate water shortages during dry periods.

Chisel plough

Mechanical implement with one or more functional components that will loosen the soil below the surface, often consisting of long shanks attached to a toolbar, which are pulled through the soil.

Root damage

Damage resulting from the pressure exerted by root systems, causing vertical or horizontal displacement of surface finishes, masonry or other construction elements on the surface or in the soil.

Compaction

Compaction is the compression and densification of soil by the expulsion of air from the voids of the soil. In contrast to consolidation it is a quick process for which short term loading is required.



‘Fragile monuments of the past’ presents an overview of the various physical factors which may lead to damage to archaeological protected monuments on land. The report also tries to define the term ‘damage’, and to list possible solutions to mitigate these physical threats. Recent years have seen extensive research and the accumulation of a wealth of practical expertise. However, until now no reference work or bibliography on physical interventions and maintenance existed, and the various sources can be difficult to find. The present publication makes some of this information accessible and offers guidelines for more detailed study and further reading.

This scientific report was written with archaeologists in mind as well as other professionals and amateurs interested in archaeology.

By offering expertise and advice, the Cultural Heritage Agency of the Netherlands aims to give the future a past.