The relationship between site characteristics of photovoltaic parks and the biodiversity impacts of management actions.

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Submitted to David Leonard, PhD

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AFFIDAVIT

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Abstract

Biodiversity supports all life on Earth, but its rapid decline due to unsustainable human activities is jeopardizing our planet's balance and resilience. Meanwhile, climate change, driven by fossil fuels is becoming the main driver of biodiversity loss. In response, energy transitions are underway in many regions with a focus on decarbonizing the energy supply by moving away from fossil fuels and towards renewable sources, including photovoltaic systems (PV). However, as large-scale PV parks are increasingly visible throughout European landscapes, their effects on biodiversity have raised concerns due to their extensive land use.

The Solar Park Impacts on Ecosystem Services Decision-Support Tool (SPIES DST) provides guidance towards PV park management actions that promote positive impacts on biodiversity. However, the impact of each management action varies from beneficial to neutral or detrimental depending on the circumstances, such that SPIES DST explains that its outputs should be interpreted considering the specific characteristics of each site.

This study seeks to provide clearer guidance to PV park operators by exploring the relationships between PV parks' site characteristics and the biodiversity impacts of management actions. To this end, comprehensive data sets were developed for three different PV parks in the Czech Republic through site visits and secondary sources. These data packages were distributed to a selection of biodiversity experts, who studied the detailed information about each park and its surrounding environment before evaluating and explaining the potential impact of 36 management actions on each of the three PV Parks. Quantitative and qualitative analyses were performed, and the findings were integrated into a comprehensive discussion of each management action.

The findings confirm the need for decision-makers in PV parks to consider the characteristics of each site when selecting appropriate management actions. In addition, the study identifies specific features that influence the impact of each management action on biodiversity (e.g., presence of invasive species, panel layout, proximity of protected areas); discusses the differences and similarities of the impact of these actions inside and outside the parks; distinguishes the most beneficial and harmful management actions for each of the three PV parks studied; and compares the findings with the guidance provided by SPIES. The study provides PV park managers with new insights into the integration of strategies to restore biodiversity into renewable energy systems to address the interconnected challenges of climate change and biodiversity loss.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES AND IMAGES

LIST OF ABBREVIATIONS

DST: Decision Support Tool

N2K: Natura 2000

MA: Management Action

PA: Protected Area

PV: Photovoltaics

RES: Renewable Energy Systems

SCDP: Site Characteristics Data Package

SPIES: Solar Parks Impacts on Ecosystem Services

1 INTRODUCTION

The quantity of energy that we consume and produce has influenced the evolution of humanity, and in the last decades, it has been increasing dramatically. This dramatic rise, mostly due to intense fossil fuel consumption, is negatively impacting the environment and consequently the society and the economy. As a result of the tremendous population growth and its influence on energy demand, along with the climate crisis and the scarcity of fossil fuels – which today's society and economy depend on – the global efforts to move away from fossil fuels towards renewable resources of energy are rising.

Accordingly, the number of ground-mounted photovoltaic (PV) parks is constantly increasing, but this expansion is raising concerns about the effects that these parks could have on biodiversity. Due to their extensive land use, PV parks offer a vast range of opportunities but also risks that their development and operations may negatively impact biodiversity (Randle-Boggis et al., 2020). As biodiversity is undeniably crucial for our existence, increasing our understanding of the effects that our activities have on biodiversity can assist in making more informed decisions and taking proactive steps towards a more sustainable future.

It is important to acknowledge that although we need "net-zero emissions" for climate change, unfortunately, due to its current state "net-zero loss" for nature is not enough; we need net-positive goals to restore nature instead of simply halting its loss (WWF, 2022a). Moreover, protecting and restoring biodiversity is not only necessary for strengthening the stability and resilience of nature but also for increasing human life security, as it is essential to mitigate natural disasters, and prevent the rise and spread of zoonotic diseases (European Commission Directorate-General for Environment, 2021). Because climate change is becoming the main driver of biodiversity loss, the shift to renewable energy from fossil fuels already has positive impacts on biodiversity, however, it is important to understand the effects of management action to maximise the positive impact that PV parks could have on biodiversity and avoid unintended negative impacts.

Although land management actions with intentions of positively impacting biodiversity in PV Parks such as installing beehives, replacing mowing with grazing or reducing cutting regimes, have proved to have a certain impact on biodiversity, their impact can vary depending on the circumstances; in some cases, they may be beneficial, while in others they may be detrimental or neutral. Solar Parks Impacts on Ecosystem Services Decision Support Tool (SPIES DST), an online evidence-based tool from Lancaster University, provides guidance into best practices to improve biodiversity in solar parks but explains that its outcomes should be interpreted with the specific characteristics of each site. Therefore, considering the 36 management actions evaluated by SPIES DST, this research intends to better understand the relationship between the characteristics of photovoltaic parks and the biodiversity impact of management actions to provide new insights that could contribute towards the integration of strategies to restore biodiversity into renewable energy systems to address the interconnected challenges of climate change and biodiversity loss.

A renewable energy company based in Europe, which owns, manages and develops solar parks in CEE (Central and Eastern Europe), and aims to improve its impact on biodiversity, accepted to collaborate in this research to identify measures that could positively impact biodiversity in its PV parks and its surroundings. Thus, three different PV parks located in the Czech Republic managed by this company were selected for this study. To answer the research question "What is the relationship between the characteristics of photovoltaic parks and biodiversity impacts of management actions?", a mixed methods research approach was performed. Firstly, data from the company owning the parks, site visits and additional secondary sources were collected to develop an in-depth data package for each site containing maps, photographs, digital drawings, additional detailed information about the characteristics of the sites and the management actions currently and previously performed. These three data packages were distributed to a selection of biodiversity experts, who studied the detailed information about each park and its surrounding environment before evaluating and explaining the potential impact of 36 management actions on each of the three PV Parks. With this, the study identifies specific features that influence the impact of each management action on biodiversity; discusses the differences and similarities of the impact of these actions inside and outside the parks; distinguishes the most beneficial and harmful management actions for each of the three PV parks studied; and compares the findings with the guidance provided by SPIES.

Humans depend on ecosystem services which have been disrupted by our unsustainable activities, in fact, among many threats, biodiversity loss also threatens food and health security (WWF, 2020). By reducing the impacts of human activities on biodiversity, social and economic benefits will follow. Moreover, this research supports not only biodiversity, but also the expansion of photovoltaic parks. As modern society depends on a reliable energy supply, and fossil fuels are becoming ever scarcer and more expensive, a clean energy transition along with biodiversity conservation and restoration will consequently benefit the economy and society. Additionally, this research could support companies and governments to comply with many of the different European Commission policies, plans, and strategies, such as EU taxonomy, RE-PowerEU plan, Green Deal, and Biodiversity strategy, and their respective objectives, such as: tackling the climate crisis, accelerate production of clean energy, protect and restore nature, reverse biodiversity loss and achieve independence from fossil fuels.

This paper is divided into seven main sections:

1 Introduction: contains a brief overview and outline of the thesis as well as its significance.

2 Literature Review: divided into three subsections provides greater context to the topic. First, it gives an overview of the importance of biodiversity, explains the main drivers of its decline, and emphasises on the need for strategies to protect and restore nature. The following elaborates on how renewable energies provide a solution to climate change, the expansion of photovoltaics, their direct and indirect environmental impacts, as well as the biodiversity risks and opportunities associated with their extensive land use and management. Lastly, the subsection of *Management actions in PV parks*, after providing an overview of SPIES DST and their evaluation of land management actions, provides a review of several studies performed in different countries that studied the effects of each of the management actions mentioned in SPIES. This last subsection explains the complexity of the impacts of each management action and how the results of studies contradict each other.

3 Methodology: describes the entire process for developing the thesis, from the selection of the research method to the analysis of expert questionnaire responses.

4 Case Study: gives an overview of South Moravia, the region where the PV Parks from this study are located, and details the differences and similarities between the three sites.

5 Results and Discussion: integrates the findings into a comprehensive discussion of each management action.

6 Conclusions: provides general conclusions and recommendations, highlights the limitations of the research, and makes suggestions for further research.

7 Bibliography: includes the list of secondary sources used in this study.

2 LITERATURE REVIEW

Biodiversity is crucial for our existence but its loss is now occurring an at alarming rate threatening balance and resilience in our planet. Although global targets such as nature–positive by 2030 and full recovery by 2050 are widely accepted and well-founded, global efforts from different stakeholders are required. Additionally, climate change, mainly driven by fossil fuels, is becoming the primary driver of biodiversity loss. As we are currently experiencing a double-interlinked crisis, climate change and biodiversity loss must be addressed together. Furthermore, renewable energy systems like photovoltaics offer a promising solution, but their environmental impacts, especially in ground-mounted PV parks due to their land use, must be considered. Tools like SPIES DST provide guidance through management actions to maximise the positive impact of solar parks on biodiversity, however, the effectiveness varies across studies. Therefore, this section, after expanding on what is mentioned above includes a review of potential land management actions to implement in PV parks and their impacts on biodiversity.

2.1 Biodiversity

2.1.1 Biodiversity loss

As humans, we fully depend on nature and its processes, it sustains the quality of the air we breathe; distributes and filters the water we drink; regulates the climate; lessens the effects of natural disasters; and supplies us with food and medicines (EC DG ENV, 2021; World Wildlife Fund, 2019). Ecosystems, which are systems of species and their environment working together in a way that resembles a network, provide us with goods and services that are essential for our existence. Besides the material aspects, nature also contributes to non-material aspects of quality of life and all dimensions of human health, like recreation, inspiration, experiences, spirituality, and culture (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019).

The benefits of natural capital to people are undeniable and irreplaceable. For centuries, civilization and human history relied on nature to develop. But now, nature is in crisis, and human activities have a strong influence on its degradation. The exponential growth of human socioeconomic activities in the last decades is putting pressure on the Earth's System, risking the stability of essential biophysical processes, and causing abrupt environmental changes detrimental to human well-being (Rockström, 2009).

Furthermore, nature's contributions to people are frequently distributed unequally over space and time and among different sectors of society, presenting trade-offs between them. Trends in material contributions of nature, such as agriculture, have increased since 1970, while regulatory and non-material contributions, such as carbon sequestration, have decreased (IPBES, 2019). Today, 75% of the world's land surface is severely changed, land degradation has negatively affected productivity in 23% of the global terrestrial area, and pollinators' decline threatens hundreds of billions of dollars of annual worldwide agricultural output (IPBES, 2019).

Biodiversity is the variety of life as well as the interactions between all living things at all levels on Earth or a specific location, including all species of plants, animals, fungi, and micro-organisms that can be found in an area and the ecosystems of which these species are part (IPBES, 2019; WWF, 2022a; WWF, 2019). Thus, everything we need to survive in nature is supported by biodiversity, which is also crucial for maintaining the life, balance, and resilience of our planet (WWF, 2019).

While biodiversity loss can occur naturally, it is now occurring at an alarming rate as a result of unsustainable human activities that are exceeding ecosystems' capacity. Population abundance and genetic diversity have decreased, biological communities are becoming every time more similar to each other, and species are losing their climatically determined habitats (IPBES, 2019; WWF, 2022a). Global wildlife populations, for example, have fallen by 60% and one million plants and animals are threatened with extinction (WWF, 2022a).

Europe, for example, has one of the world's lowest levels of biodiversity intactness, and although wildlife population decreases appear to be among the lowest according to the WWF Living Planet Index, this is due to the fact that much biodiversity had already been depleted by the baseline year of 1970 (WWF, n.d.; 2022b).

As living organisms interact in dynamic ecosystems, the reduction in abundance or extinction of species can have wide-ranging consequences. Biodiversity loss can present dangerous threats such as the increased vulnerability of food supplies due to pests and diseases, freshwater shortages or quality reductions, ecosystem imbalances leading to the emergence of zoonotic diseases, species extinctions, natural catastrophes, and a decline in ecosystem capacity to absorb CO_2 emissions, among other things (WWF, 2022a)

Currently, changes in land and sea use are the major direct driver of biodiversity loss and the degradation of ecosystems and their services, followed by climate change, overexploitation of natural resources, pollution, and invasive alien species (WWF, 2022a; IPBES, 2019). Agricultural expansion is by far the most widespread form of land-use change, accounting for more than one-third of the terrestrial land area and for about 90% of worldwide deforestation (United Nations Department of Economic and Social Affairs, 2022; IPBES, 2019). Habitat fragmentation, another form of land use change, by breaking ecological connectivity, threatens biodiversity conservation and ecological processes (such as pollination), reduces overall habitat area and quality, increases isolation from other habitat patches, disrupts food webs and species' ability to migrate, disperse, and find mates, among other things (WWF, 2022a). Cities expansion, land degradation, and landscape/seascape management intensification are other harmful forms of land use change (IPBES, 2019; WWF, 2022a).

Climate change is a critical direct driver of biodiversity loss, and it is likely to become the primary driver if global warming is not limited to 1.5°C (WWF, 2022a). This is a driver that amplifies the impact of other causes of biodiversity loss forming a positive feedback loop *(see figure 1).* Extreme weather events, such as wildfires, heatwaves, floods, and droughts, have become more often and more intense, affecting many elements of biodiversity, including species distribution, phenology, population dynamics, community structure, and ecosystem function (IPBES, 2019; EC DG ENV, 2021). Moreover, according to the European Commission DG ENV (2021), these extreme weather events are driving mass mortality events in trees, birds, bats, and fish. Beetles and moths that attack northern forests, for example, are surviving better in warmer winters and producing more generations each year due to the extended growing season, triggering huge die-offs of trees in North America and Europe's northern temperate and boreal zones (EC DG ENV, 2021).

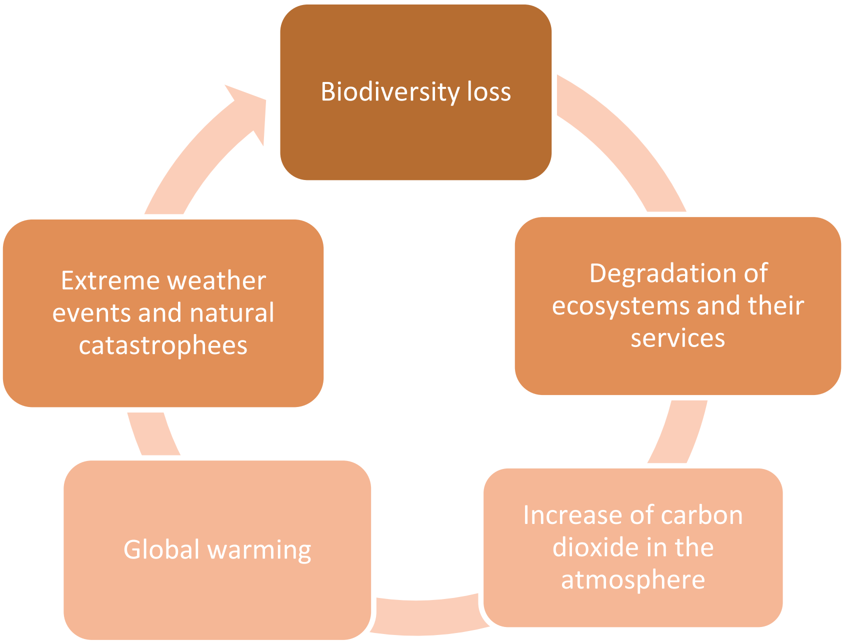


FIGURE 1: CLIMATE CHANGE POSITIVE FEEDBACK LOOP.

Overexploitation of natural resources, in other words, extraction of natural resources exceeding sustainable levels, can alter nature's balance and disrupt the environment. Likewise, land-use change brought on by certain extraction methods can negatively affect wildlife populations, soil quality, greenhouse gas emissions, and other ecosystem services (IPBES, 2019). As populations and per capita consumption rises so does the extraction of natural resource. Between 1970 and 2010, the extraction of living and non-living resources, such as deforestation, mining, fishing or hunting, increased sixfold, and the demand for materials used in construction and industry quadrupled (IPBES, 2019). Moreover, between 2005 and 2015, the consumption of biomass, fossil fuels, metal ores, and non-metallic minerals doubled (IPBES, 2019). Exploitation is the second biggest threat to terrestrial ecosystems after habitat loss; each year over 10 million hectares of forest are destroyed and over 40,000 species are at risk of extinction in the near term (UN DESA, 2022; IPBES, 2019).

Another major factor contributing to biodiversity loss is pollution, which also negatively affects human health (EC DG ENV, 2021). Despite the improvements in some places, pollution levels in air, water and soil have been rising; freshwater and marine water quality, as well as soil and global atmosphere, have been severely impacted by greenhouse gas emissions, untreated urban and rural waste, pollutants from industrial, mining, and agricultural activities, oil spills, and toxic dumping (IPBES, 2019).

Furthermore, in the last decade, drained nitrogen fluxes from fertilizers used in agricultural production increased four to twentyfold; this is a relevant threat as nutrients movement from fertilizer can stimulate excessive plant growth and, in extreme cases, hypoxia or oxygen-depleted "dead zones" as well as harmful algal blooms (IPBES, 2019). Regarding solid waste, the fastest-growing category of electronic waste consists of hazardous waste and strategic metals (rare earth materials), which must be isolated before disposal or recycling as informal recycling is harmful to health (IPBES, 2019). Nevertheless, electronic waste is insufficiently controlled and many times it builds up in landfills and is sent to developing countries (IPBES, 2019). Additionally, plastic pollution is escalating and is a particular concern as small plastic fragments are difficult to remove from the environment and can be ingested, affecting marine, freshwater and terrestrial species as well as humans through food chains (IPBES, 2019).

Additionally, the increase in trade and human population dynamics has led to a 40% increase in cumulative records of alien species since 1980, with no signs of slowing down (IPBES, 2019). Invasive alien species pose a significant threat to nearly one-fifth of the Earth's surface, including many biodiversity hotspots, as these species impact native species, ecosystem functions, nature's contributions to people, economies, and human health (IPBES, 2019). In Europe, for instance, these species represent a major threat to native plants and animals; around 19% of the species now considered threatened in Europe are under threat from invasive alien species (EC DG ENV, 2021). Unfortunately, the introduction of new invasive alien species appears to be at an all-time high, and the threat is compounded by the fact that many invasive alien species facilitate the outbreak and spread of infectious diseases, further endangering humans and wildlife (IPBES, 2019; EC DG ENV, 2021).

2.1.2 Nature positive

Because ecosystem products and services are necessary to our existence, cannot be replaced, and are in serious decline, human activities must respect ecosystem capacity and modify the way natural capital is managed. Since the 1980s, numerous organisations and individuals have called for action to ensure a sustainable future, and in response, many sustainability goals and targets have been established at the local, national, and global levels, including the Aichi Biodiversity Targets and the 2030 United Nations Sustainable Development Goals (SDGs) (IPBES, 2019). However, progress towards biodiversity conservation and restoration has largely failed, and with the current trajectories, many international targets will not be achieved (WWF, 2022a; IPBES, 2019). For example, none of the 20 Aichi biodiversity targets set by the Convention on Biological Diversity (CBD) for 2020 were entirely met, and in certain cases, the situation in 2020 was worse than in 2010 (WWF, 2022a). As a result of that failure, the Post-2020 Global Biodiversity Framework, which was finalised in 2022 during COP15 (15th edition of the Conference of the Parties to the Convention on Biological Diversity (CBD)), established new international targets focused on protecting and restoring nature.

According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2019), as the paths to achieving global environmental goals range significantly across geographic contexts, different changes are needed to achieve these goals at all scales. Therefore, it has been agreed that single targets have a limited ability to address biodiversity declines and that changes towards sustainability need to be profound, reflexive, systemic, and strategic (IPBES, 2019). In addition, according to the WWF Living Planet Report (2022a) we are currently facing the double, interlinked emergencies of human-induced loss of biodiversity and climate change, which are not only environmental but also economic and social issues that must be addressed together and line with the 17 UN Sustainable Development Goals (SDGs).

Although we need ¨net-zero emissions¨ for climate change by 2050, unfortunately, net-zero loss for nature is not enough; due to the current state of biodiversity, we need a net-positive goal to restore nature instead of simply halting its loss (WWF, 2022a). Therefore, nature-positive by 2030, which means more nature by the end of this decade than at its start, and full recovery of nature by 2050 are today well-founded and widely accepted global goals. Moreover, protecting and restoring biodiversity for a nature-positive future not only strengthens nature's stability and resilience but also benefits economic and human well-being by preventing zoonotic diseases, mitigating natural disasters, and improving climate, food, and water security (IPBES, 2019; WWF, 2022a)

To achieve a nature-positive future, efforts from governments, as well as businesses, organizations, and individuals, are required. According to WWF (2022a) governments should protect endangered species and spaces, fund ecological restoration, shift to sustainable production and consumption, require businesses to conduct human rights and environmental due diligence across their supply chains, and better regulate and restrict fossil fuels, extractive industries, and ecosystem-degrading activities.

The European Union, for instance, adopted in 2020 the EU Biodiversity Strategy for 2030. With the broader vision of all the world’s ecosystems being restored, resilient, and adequately protected by 2050, this strategy aims to put Europe's biodiversity on the path to recovery by 2030 (European Commission, 2020). The strategy is divided into four pillars which include specific actions and commitments to be achieved by 2030; these pillars are: (1) Protect Nature, (2) Restore Nature, (3) Enable Transformative Change and (4) EU Action To Support Biodiversity Globally (EC DG ENV, 2021). Some of the commitments and targets included in this strategy are displayed in the table below.

Commitments and targets included in EU Biodiversity Strategy 2030	
Protecting Nature in the EU	**Restoring Nature in the EU**
• Protect 30% of the EU's land and 30% of its seas (currently 18% of the land and 3% of the sea is protected). • Strictly protect 10% of the EU's land and 10% of its seas (currently 3% of the land and 1% of the sea is strictly protected). • Create and integrate ecological corridors to prevent genetic isolation, allow for species migration and climate adaptation, and maintain and enhance healthy ecosystems. • Effectively manage all protected areas, defining clear conservation objectives and measures, and monitoring them appropriately.	• Ensure 30% of EU-protected species and habitats are in favourable conservation status or have positive trends. • Reverse the decline of pollinators. • Reduce the use of chemical pesticides by 50%. • Ensure that at least 10% of the agricultural area is under high-biodiversity landscape features. • Place at least 25% of agricultural land under organic farming management. • Restore at least 25,000 km of free-flowing rivers. • Plant at least 3 billion new trees in the EU. • Make significant progress in remediating contaminated soil sites. • Manage established invasive alien species and decrease the number of Red List species they threaten by 50%. • Prioritise win-win solutions for biodiversity and renewable energy, such as solar-panel farms that can be combined with biodiversity-friendly soil cover.

TABLE 1: COMMITMENTS AND TARGETS INCLUDED IN EU BIODIVERSITY STRATEGY 2030 (SOURCE: EC DG ENV, 2021).

Regarding businesses, these not just play a significant role in the systemic transformation towards a nature-positive future, but as the flow of ecosystem services provided by nature underpins the core operations of many business sectors, biodiversity loss has been identified as one of the greatest macro-scale risks to businesses (zu Ermgassen et al., 2022). Therefore, businesses and financial institutions are reorienting sustainability strategies to regenerate and recover nature to ensure supply chain and production stability (The Biodiversity Consultancy, n.d.). Over the last two decades, for instance, "no net loss" or "net positive impact" commitments have become more common, with a focus on applying the mitigation hierarchy (avoid, minimise, restore, offset) (zu Ermgassen et al., 2022). Furthermore, in a similar way that going carbon neutral requires changing company strategy, lowering GHG emissions, and investing in compensatory measures, going nature-positive for a business means transforming its processes, activities, and strategy to achieve both positive outcomes for nature and long-term business sustainability (The Biodiversity Consultancy, n.d.).

Nonetheless, it is crucial to acknowledge that we live in a complex and interconnected system and therefore failure to accomplish biodiversity loss and climate change targets puts practically all SDGs at risk, including food and water security, excellent health for all, poverty alleviation, and a more equal society (WWF, 2022a).

2.2 Photovoltaic Parks

2.2.1 Climate change and the urge for renewable energy systems

Climate change is a current well-known and documented crisis that presents a significant threat to the planet's ecological and human systems. Human activities, such as the burning of fossil fuels, are causing significant increases in atmospheric concentrations of greenhouse gases, which leads to a rise in global temperatures.

With the human-induced rising temperatures, the world is experiencing an increase in the frequency and intensity of extreme weather events such as wildfires, heatwaves, droughts, cyclones and floods. These extreme weather events are already affecting billions of people and may have an irreversible impact on ecosystems throughout the world (UN DESA, 2022). In 2021, for example, these events occurred on every continent, in Canada temperatures broke records, Europe and Asia experienced devastating floods, and parts of Africa and South America faced severe droughts (UN DESA, 2022).

According to the Intergovernmental Panel on Climate Change (IPCC, 2022b), human activities are considered to have caused an increase in global temperature of about 1.0°C over pre-industrial levels and global warming is likely to reach 1.5°C between 2030 and 2052 if major changes to reduce greenhouse gas emissions are not made. Moreover, if the Paris Agreement's goal of limiting global warming to 1.5°C is not achieved, the globe might suffer negative impacts which could be permanent and it has been scientifically proven that with each additional increment of global warming, the predicted changes in extremes would get more pronounced (UN DESA, 2022; IPCC, 2022a).

The IPCC advises that global greenhouse gas emissions peak before 2025, fall by 43% by 2030, and reach et Zero by 2050 in order to keep warming to 1.5°C above pre-industrial levels (UN

DESA, 2022). Unfortunately, current national actions and commitments are insufficient to meet these targets; under current commitments, greenhouse gas emissions are expected to rise by nearly 14% over the next decade (UN DESA, 2022).

The production and consumption of energy have been increasing together with the global population and technological advances. Since the Industrial Revolution, oil, coal, and gas have been the primary sources of energy for most countries, and this trend continues today with our energy infrastructure depending heavily on these fossil fuels (Ritchie et al., 2022; Smets et al., 2016) However, this dependency has major implications for the current climate crisis as the burning of fossil fuels for energy is responsible for approximately three-quarters of global greenhouse gas emissions (Ritchie et al., 2022). Additionally, fossil fuels are responsible for large amounts of local air pollution, which apart from its contribution to biodiversity loss, has severe implications for human health (Ritchie et al., 2022).

The depletion of fossil fuels is another issue. Fossil fuels are "millions and millions of years of solar energy stored in the form of chemical energy" that humans are depleting "much faster than they are generated through the photosynthetic process in nature" (Smets et al., 2016 p.30). Therefore, it will be difficult to meet future energy demands if we continue to rely on fossil fuels, which are becoming scarcer and more difficult to extract as we consume more of them.

In order to extract fossil fuels, new and unconventional methods have been developed, such as hydraulic fracturing to produce gas and the extraction of oil from Canada's tar sands (Smets et al., 2016). The extraction of fossil fuels using these methods requires a lot more energy and contributes to climate change as well as other environmental and social issues. The Deepwater Horizon oil spill in the Gulf of Mexico in 2010 served as an example of the new technological risks that come with offshore drilling in areas with ever-deeper water depths (Smets et al., 2016).To mitigate the worst impacts of the climate crisis, there is an urgent need for action to reduce greenhouse gas emissions and promote a transition to a sustainable, low-carbon economy where renewable energy systems play an important role.

Currently, over one-third of the world's electricity comes from low-carbon sources such as nuclear and renewables, although a smaller portion of the world's total energy production does Ritchie et al., 2022). It is estimated that nuclear power accounts for 10% of global electricity production, while renewables account for 26% (Ritchie et al., 2022). Nevertheless, nuclear fuels as well as fossil fuels are not considered renewable sources of energy because they are not "refilled" by nature, at least not in a time frame that is useful for human use (Smets et al., 2016).

Renewable energy sources such as hydro, wind and solar, in contrast, are energy sources that are replenished by natural processes at a rate similar to or faster than the rate at which they are consumed by humans (Smets et al., 2016). This contributes to the increase of international efforts to rise the share of renewable energy sources in the world's energy mix *(See figure 2).*

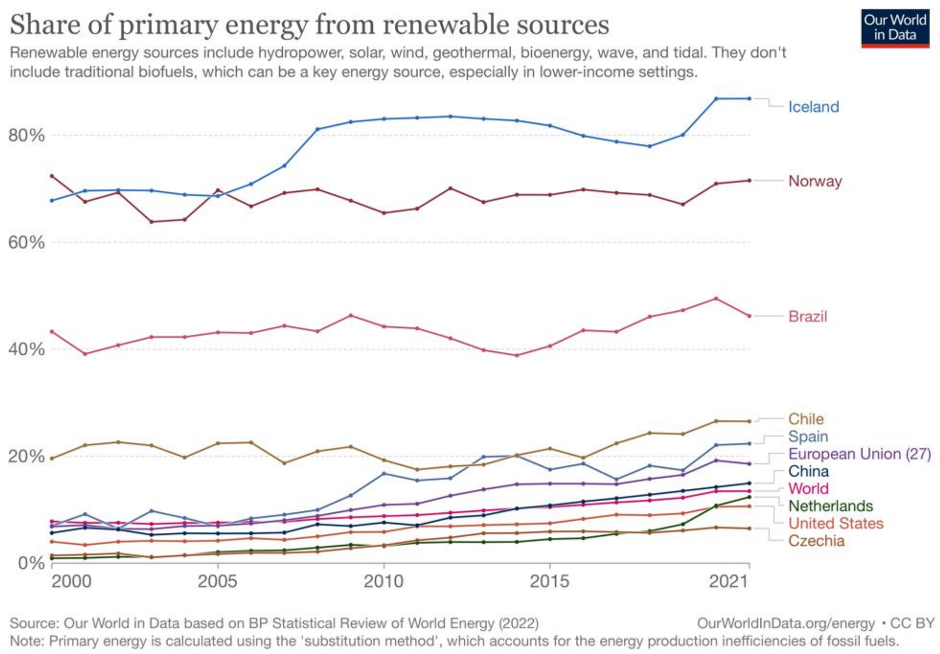


FIGURE 2: SHARE OF PRIMARY ENERGY THAT COMES FROM RENEWABLES (SOURCE: RITCHIE ET AL., 2022).

Although the world is shifting toward renewable energy sources not only to reduce greenhouse gas emissions but also to reduce other social, economic, and environmental impacts of non-renewable sources, there is still a large gap between countries. The share of renewables in the European Union energy mix for example, even though is above the world average, still has significant space for improvement.

Moreover, to fight the climate crisis the European Union is aiming to reduce net greenhouse gas emissions by at least 55% (compared to the 1990 level) by 2030, and to become climate-neutral by 2050. As the energy sector is responsible for over 75% of the EU's greenhouse gas emissions, increasing the proportion of renewable energy is one of the key strategies of the EU to achieve its climate objectives (EC, n.d.). Since 2014, the target to increase the proportion of renewable energy sources in the EU's overall energy mix by 2030 has been constantly rising. Initially set at 27%, the target was raised to 40% in 2021. However, with the implementation of the REPowerEU plan in 2022, the target was further increased to 45%. This plan, created by the European Commission after the “unprovoked and unjustified military aggression against Ukraine”, aims to accelerate the transition to clean energy to lessen the EU's dependency on Russian fossil fuels and achieve a more resilient energy system (EC, 2022).

2.2.2 Photovoltaics and their interaction with the environment

Nearly every process that occurs on the surface of our planet uses energy from the sun, which can then be transformed using a variety of technologies into electricity, heat, and chemical energy (Smets et al., 2016). Moreover, the share of electricity that comes from solar technologies has been constantly rising in the last decades (Ritchie et al., 2022) *(see figure 3).*

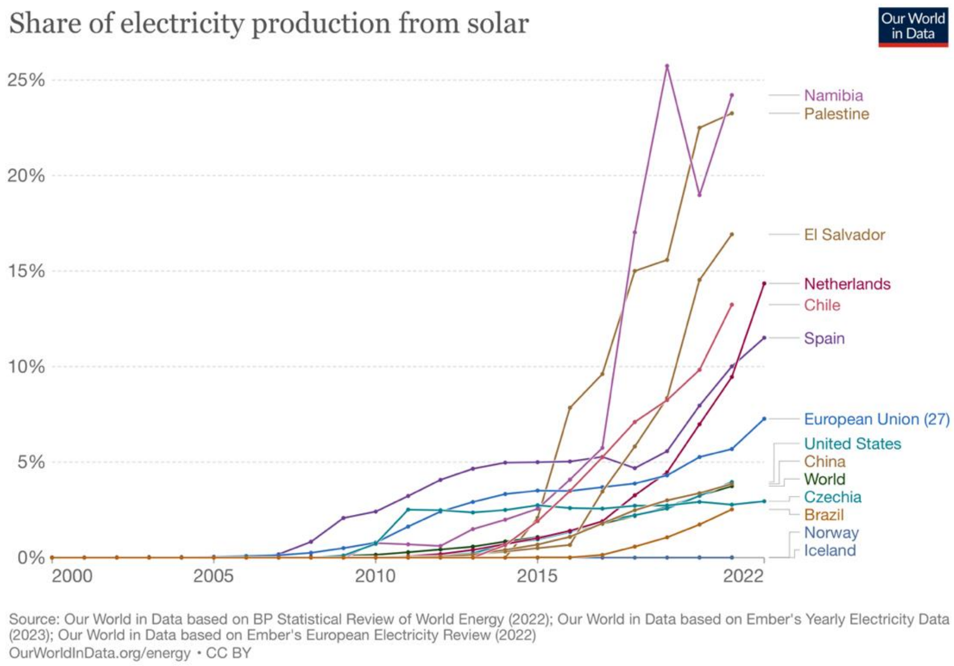


FIGURE 3: SHARE OF ELECTRICITY THAT COMES FROM SOLAR (SOURCE: RITCHIE ET AL., 2022).

Photovoltaics (PV) is a method of converting energy from sunlight directly into electricity using devices based on semiconductor materials. Moreover, their application is growing rapidly due to their potential to mitigate climate change, their flexibility, and the vast improvements in both their efficiency and cost that have occurred in recent years (Kabir et al., 2018).

Currently, solar PV accounts for approximately 3.6% of global electricity generation and is the third largest renewable energy technology after hydropower and wind (International Energy Agency, 2022). Although it is constantly growing and achieved 22% growth in 2021, solar PV requires annual average generation growth of about 25% during 2022-2030 to be aligned with the target of Net Zero Emissions by 2050 (IEA, 2022). Therefore, greater efforts from public and private stakeholders as well as more ambitious goals are being suggested by International

Energy Agency (2022). In addition, China was responsible for the largest contribution to solar PV growth in 2021 (38%) due to important capacity, followed by the United States (17%) and European Union (10%) (IEA, 2022).

Photovoltaic installations can be mounted on the ground, on rooftops, on walls, or even floating in different water bodies. Additionally, the mount can be fixed, or it can use a solar tracker to follow the sun as it moves across the sky. Generally, PV systems are known to be safe for the environment once fully installed as they do not produce any noise, nor emit any toxic or greenhouse gases (Rabaia et al., 2021, Tsoutsos et al., 2005). However, solar cell and panel production have some negative effects on human health and the environment as hazardous and flammable materials are used although in small amounts during the manufacturing process (Rabaia et al., 2021). The effects of production differ depending on the type of solar cell and the manufacturing technology used.

The processes of transporting, installing, and disposing of PV modules consume a considerable amount of energy and have other negative environmental consequences that must not be neglected (Rabaia et al., 2021). Nevertheless, GHG emissions associated with solar power generation, including manufacturing, installation, operation, and maintenance, are minimal (Kabir et al., 2018). While CO2 emissions per kilowatt-hour generated by coal range between 0.64kg and 1.63kg, and for natural gas between 0.27kg and 0.9kg, the range for solar power is between 0.03kg and 0.09kg, resulting in an emission ratio of 18:9.5:1 (Kabir et al., 2018).

Unlike fossil fuel plants, solar technologies do not require water to operate and are more labour-intensive; on average, solar energy can create more jobs per unit of electricity production than fossil fuels (Kabir et al., 2018). Furthermore, solar energy is a reliable source of energy as it does not need to be considered that it will eventually be depleted, making it an excellent alternative to fossil fuels and one of the most viable solutions to the current global warming crisis (Kabir et al., 2018).

2.2.3 Photovoltaic parks and their interaction with the environment

Despite their challenges, utility-scale is still the most competitive source of PV generation in most parts of the world, accounting for 52% of global solar PV capacity additions in 2021, followed by the residential (28%) and commercial and industrial (19%) segments (IEA, 2022). In addition, ground-mounted photovoltaic solar parks have become a popular way to generate large-scale renewable electricity that is usually fed into the grid. Their size ranges from 1 to 100 acres, and they are typically located in rural areas (Burke et al., 2015).

Quantifying the environmental impacts of PV Parks is challenging, however, understanding them is becoming more urgent due to their high land take per unit of energy produced, their exponential growth rates and their contribution to sustainable development (Armstrong et al., 2021). Although this understanding is still emerging, further research is necessary for different ecosystems, climates, and management practices.

The impact on wildlife varies depending on the specific characteristics of each site; while they may not be suitable for some areas, it is proven that they can enhance biodiversity in others (Burke et al., 2015; Montag et al., 2016). For example, vegetation diversity increased relative to previous land use in a UK solar park due to differences in climate and management, while perennial plant cover and structure were lower in a Californian desert solar park due to differences in construction techniques (Armstrong et al., 2021). Moreover, the impact of land use on natural ecosystems depends on factors like topography, the area of land covered by the PV system, the type of land, the distance from natural beauty or sensitive ecosystems, and biodiversity (Tsoutsos et al., 2005).

The construction and operation of PV parks can have both positive and negative impacts on the environment. One significant concern is the large land area required for utility-level installations, which could potentially reduce cultivable land (Rahman et al., 2022). Likewise, the installation of their infrastructure can require extensive landscape modification and imply negative impacts on the environment resulting from construction activities (Tsoutsos et al., 2005). These modifications include removing vegetation, grading the land, compacting the soil, and building access roads (Hernandez et al., 2014). However, neglected mining areas, contaminated brownfields, and transport corridors could be used instead of cultivable land.

Once installed, the presence of PV panels on agricultural land is likely to cause shading, changes to wind flow, alterations in temperature, and changes to rainfall distribution, which can impact soil moisture (Burke et al., 2015). Also, some structures used to maintain the angle of PV panels such as concrete structures, can affect the distribution of heat and water in the soil, which could lead to soil degradation and hampered vegetation restoration (Rahman et al., 2022). These changes in the environment caused by the presence of PV panels can alter vegetation composition, which explains why vegetation under the panels normally appears to be different (Uldrijan et al., 2021). Although PV Parks alter the site conditions where they are placed, it has been proven that vegetation normally adapts to these changes and that these changes could be beneficial for some locations instead of a threat as they can create conditions for species-rich plant communities (Uldrijan et al., 2021).

PV parks offer opportunities to create different habitats, provide a refuge for plants and animals and enhance pollinator biodiversity by mitigating some of the most important drivers of pollinator decline (Peschel, 2010; Blaydes et al., 2021). It has been repeatedly demonstrated that solar parks are relatively safe locations where pollinator habitats and honeybee hives can be established without intentional or unintentional human damage and that climate niches provided by solar panels could mitigate the effects of climate change on pollinators (Armstrong et al., 2021). They also provide the chance to reclaim degraded land and improve the ecological value of sites through regular maintenance; by converting sites of low environmental significance into solar parks, areas of grassland can be created (Tsoutsos et al., 2005, Peschel, 2010). In addition, the regular maintenance required for these open grassland areas, such as sheep grazing or mowing can create valuable, species-rich habitats, which are necessary for the survival of many animal and plant species (Peschel, 2010). Furthermore, integrating these improved sites into a biotope network can have benefits on biological diversity that go beyond the individual solar parks themselves (Peschel, 2010).

Although it has been proven that sites with PV installations can create conditions for species-rich plant communities, it is important to mention that the management practices chosen on the site influence the potential impacts of PV parks on the environment. For example, the often-debated reflection effect, which claims that modules reflect sunlight like water, attracting water insects and encouraging them to lay eggs on them creating an "ecological trap", can be reduced by white markings (Peschel, 2010). Additionally, research has shown that in locations where solar parks practise wildlife-focused management, a rise in biodiversity can be seen across a variety of species groups (Montag et al., 2016). To make a significant contribution to the preservation and promotion of regional genetic diversity, for instance, it is essential to use native seeds and plants whose environmental requirements match the site characteristics and that have been acquired from within a defined source region as the choice of vegetation used can have an impact on genetic biodiversity (Peschel, 2010). Furthermore, solar parks are frequently fenced for security reasons, and although fencing should be avoided, regular passages and at least 10 to 15 cm of ground clearance under the fence can preserve the natural functional relationships between the fenced-in solar park and the surrounding area by allowing animals, such as mammals, to pass through the area occupied by the PV park without destroying habitats or isolating and fragmenting animal populations (Peschel, 2010).

PV parks are usually designed and managed with a single focus on producing renewable energy, utilising locations with high-quality solar resources that can be easily connected to power grids or local loads. However, photovoltaics can be designed to work in synergy with other, social, economic, or environmental goals. Agrivoltaics, for example, involves installing solar panels on farmland to provide shade for crops while also producing clean energy; this strategy can provide opportunities for crops since the shadow of the panels can reduce water loss by evaporation. Another example is floating PV systems, which reduce evaporation in water bodies and could improve water quality apart from maintaining the efficiency of the PVs by keeping them cool (Exley et al., 2021). These examples, as well as PVs installed on rooftops, demonstrate the potential for photovoltaics to develop synergies and enable the use of land for multiple purposes. Likewise, as low-carbon energy demands and land use pressures rise, synergies between renewable energy and environmental goals are crucial (Armstrong et al., 2021). PV Parks that implement wildlife-focused management which includes sowing diverse seed mix, limiting the use of herbicides, conserving grazing or mowing and managing marginal habitats for wildlife, could increase biodiversity (Montag et al., 2016). In addition, the active monitoring of the environment contributes to the improvement of future measures for the protection of flora and fauna (Peschel, 2010).

2.3 Management Actions in PV Parks

2.3.1 SPIES as a decision tool

In response to energy decarbonisation, the number of ground-mounted solar parks is increasing globally. While these parks offer an opportunity to deliver ecosystem co-benefits, there is also a risk that their construction and operation could pose negative impacts on ecosystems (Randle-Boggis et al., 2020). Therefore, academics at Lancaster University and the University of York, along with the solar industry, ecologists, nature conservationists, and farming stakeholders, developed the Solar Park Impacts on Ecosystem Services decision-support tool (SPIES DST) (Randle-Boggis et al., 2020).

SPIES DST is an evidence-based online resource that demonstrates how solar parks can be managed to maximise ecosystem service provision and assist practitioners in making more informed environmental management decisions (Yeo et al.., 2020). This tool is supported by 704 pieces of evidence extracted from 457 peer-reviewed academic journal articles that evaluated the impacts of land management on ecosystem services (Randle-Boggis et al., 2020). Moreover, all the sources of literature supporting each piece of evidence are pointed out for users to be able to search and read the complete article.

In addition, the pieces of evidence can be arranged by "management actions", which provides a list of environmental outcomes that are achieved by certain management actions or by "ecosystem service", which provides a list of management actions that will affect the achievement of a desired environmental outcome (Yeo et al.., 2020). Some of the ecosystem services considered in the tool include air quality, flooding, climate, pollination, food provision, cultural services and habitats and biodiversity maintenance. The summary of management actions for the desired environmental outcome of "Maintaining habitats and biodiversity" is shown in the following table.

Maintaining Habitats and Biodiversity (SPIES Summary)		
Negative impact	**Neutral**	**Positive impact**
• Cease grazing if previously grazed • Cease mowing if previously mowed • Remove mowing clippings from wild-flower meadows • Install/maintain bee hives	• Reduce pollution and green waste inputs into ditches • Lime soil to adjust pH and increase organic storage • Replace poor topsoil with quality donor soil • Use geotextiles to prevent peat erosion • Remove mowing clippings from semi-natural grassland	• Graze later in the year • Reduce grazing intensity if previously grazed • Replace mowing with grazing if previously mowed • Block/remove drainage ditches or reduce intensity • Connect habitats • Create/maintain artificial refugia • Create/maintain artificial wetlands or wet features • Create/maintain beetle banks • Create/maintain buffer zones/field margins/set-aside • Install/maintain bat boxes • Install/maintain bird boxes • Install/maintain subsurface drains • Install/maintain Sustainable Drainage Systems (SuDS) • Reduce/cease pesticide and fertiliser use if previously used • Create/maintain areas of bare ground • Cut sod • Remove topsoil • Transfer hay/diaspores to soil • Allow trees to grow in hedgerows • Cut hedges in winter • Maintain low hedges • Mow in strips/patches, spread over time • Mow later in the year • Plant/maintain hedgerows/shelterbelts • Plant/maintain wild flower/nectar seed meadows • Reduce hedge cutting frequency to once every two years • Reduce mowing regime to once a year

TABLE 2: SPIES MANAGEMENT ACTIONS FOR MAINTAINING HABITATS AND BIODIVERSITY (SOURCE: SPIES DST, N.D.)

Although the literature included in SPIES DST comes from different countries, the tool is specifically tailored to the UK landscape (Yeo et al., 2020). Moreover, SPIES DST explained that…

> *"Due to the nature of the evidence base, outputs from SPIES are indicative rather than prescriptive and should be interpreted with reference to local environmental and ecological contexts. As such, it is recommended that users seek the advice of a professional ecologist before carrying out specific interventions." – SPIES DST, n.d.*

2.3.2 Grazing and mowing

When vegetation exceeds a certain height close to the PV panels it blocks the sunlight that the panels receive which results in a decrease in energy production. Therefore, vegetation control practices such as mowing and grazing are common management practices inside the PV Parks. Many studies about different grasslands in Belgium (Jacquemyn et al., 2011), the UK (Walker et al., 2011), Sweden (Dupré et al., 2001), France (Fonderflick et al., 2014) Finland (Hellström et al., 2003), and the Czech Republic (Pavlů et al., 2007), among others, have proved that abandonment of managed sites, meaning ceasing grazing or mowing, is a serious threat to biodiversity, as it can cause species biodiversity to decline, especially species dependent on short swards (Jacquemyn et al., 2011; Walker et al., 2011). When ceasing these management practices, tall grasses can dominate the aboveground biomass and, overtop most of the accompanying subordinate species, resulting in a decrease of light penetration to the soil (Jacquemyn et al., 2011). This leads to a decline in species richness as a result of competition for light and a decrease in germination possibilities due to the loss of gap formation (Jacquemyn et al., 2011). Moreover, the lack of any management restricts the long-term survival of some perennial herbs (Brys et al., 2004).

The intensity, frequency and timing of mowing and grazing are very much related to the effects that these practices have on the environment and as well as abandonment, and unsuitable management can reduce species richness or place a threat to specific species. For instance, a study in semi-natural pastures in central Sweden comparing grazed sites from mid-May, and mid-July, found a higher abundance of flowers on later grazing which led to a higher number of flower-visiting insects (Sjödin, 2007). Likewise, a study in Germany studying Orthoptera, argued that an early date of mowing or grazing could eliminate most of the present less mobile nymphs, while a midsummer cut could potentially disturb reproducing adults (Chisté et al., 2016). However, another study in the UK demonstrated an increase in species richness in spring and winter grazing (Bullock et al., 2001).

Apart from differences in studies, avoiding uniformity and ensuring habitat heterogeneity has shown to be an important target of contemporary environmentally friendly grassland management (Rada et al., 2014). Likewise, a more heterogeneous layout increases the availability of food resources and habitat suitability, supporting a wider range of insect species (Zhu et al., 2012).

Land use intensification has been constantly demonstrated to negatively impact biodiversity. However, because the main purpose of mowing is to avoid the reduction of energy production, although is normally a cost for the PV Parks, it is done as many times as necessary. As modern mowing can be done not just manually but also with heavy machinery, its impacts could present a threat to some species. For instance, the negative effects of mowing on Orthoptera, have primarily been associated with the killing of individuals through physical intervention, destruction of essential food resources, increased predation pressure, and disruption of favourable microclimate (Chisté et al., 2016)

To guarantee the maintenance of species richness the recommendation of mowing frequency varies between scientific studies, although a majority suggest reducing mowing regimes (Uldrijan et al., 2021), some suggest few cuts per year (Bullock et al., 2001), and others suggest once per year or less. However, diversifying cuts in time and space, such as mowing in strips or patches, is recommended as an alternative to avoid uniformity and reduce negative effects on meadow invertebrates (Cizek et al., 2012). Moreover, a study in a productive, species-poor meadow in the Czech Republic demonstrated that large-scale synchronised mowing reduces the diversity and population sizes of common arthropods and synchronises sward regrowth, threatening species that need short-sward patches (Cizek et al., 2012). Therefore, it is argued that "any diversification of mowing operations will contribute to the diversity of animal resources, hence species diversity" (Cizek et al., 2012). Additionally, removing mowing clippings from wildflower meadows and semi-natural grassland has been mentioned in the literature with mixed opinions as other management actions (Uldrijan et al., 2021).

Research comparing the effects of grazing and mowing on grassland conservation has shown that the effectiveness of each technique may vary depending on different characteristics of the grassland, such as its type, and the species targeted for conservation (Tälle et al., 2016; Smith & Cherry, 2014). However, in comparison to mowing, grazing might generally have a more favourable impact on the conservation of semi-natural grassland as it appears to be more patchy and gentle cut (Tälle et al., 2016; Chisté et al., 2016). Moreover, as animals are slower and more selective, they facilitate avoidance by some species such as grasshoppers and due to animal faeces, grazing is also linked to nutrient recycling and high nitrogen availability (Chisté et al., 2016). Another benefit of grazing is that species that lay their eggs in plant parts are likely to be less disturbed by grazing than by mowing (Chisté et al., 2016).

Goats, sheep, cattle, and horses are some of the livestock that can be used for grazing. However, studies have shown that the different sizes of herbivores have varying impacts on the surrounding ecosystem (Chisté et al., 2016; Prior et al., 2011). Moreover, the intensity is an important factor to consider, as grazing could reduce species richness and abundance even more than annual mowing or short-term abandonment due to plant resource removal through overgrazing and trampling; directly affecting herbivores such as leafhoppers or butterflies, or indirectly affecting predatory arthropods like spiders, which suffer from decreased prey abundance and a loss vegetation heterogeneity (Kormann et al., 2015). Furthermore, too much grazing or the complete removal of livestock could be detrimental for some species, such as common breeding birds (Tälle et al., 2016). Nevertheless, while extensive sheep grazing tends to homogenise spatial vegetation structure, rotational grazing allows for spatial and temporal heterogeneity in vegetation structure (Fonderflick et al., 2014).

2.3.3 Soil, pollution, chemicals and drainage

Due to land-use intensification or abandonment, species-rich calcareous grasslands on nutrient-poor soils are becoming rare in Europe and the remaining grasslands often are too small and fragmented to sustain healthy populations of specialised plant and animal species (Kiehl & Pfadenhauer, 2007). Moreover, intensive grassland management has negatively affected many taxa, including grasshoppers, butterflies, broadleaf plants and birds, and high residual soil fertility as a result of intensive farming is likely to severely limit the enhancement and long-term maintenance of plant diversity (Pywell et al., 2007).

Restoring suitable habitat conditions on former arable land is essential for the establishment and long-term survival of target species and the prevention of the spread of non-target species like common arable weeds or potentially dominant ruderals (Kiehl & Pfadenhauer, 2007). However, the successful restoration of previously intensively managed grasslands faces several challenges, including high soil fertility and degraded soil faunal communities (Resch et al., 2019).

One of the solutions to overcome these challenges is the removal of the topsoil. Topsoil removal benefits species-rich plant communities and improves the establishment and survival of target species, but it is an expensive method that severely disturbs soil communities and has an adverse impact on the physical and chemical processes and properties of the soil, which conflicts with soil conservation targets (Resch et al., 2019; Kiehl & Pfadenhauer, 2007). Furthermore, a combination of removing the topsoil and introducing propagules of target plants has become one of the major tools for various European countries to restore former species-rich grasslands (Resch et al., 2019). Additionally, there is evidence that severe disturbance involving turf removal followed by seed addition has been an effective and reliable means of increasing grassland diversity (Pywell et al., 2007). Other management actions regarding soil in PV Parks include liming soil to adjust pH and increase organic storage, replacing poor topsoil with quality donor soil, transferring hay/ diaspores to the soil, using geotextiles to prevent peat erosion, and creating and/or maintaining areas of bare ground (Uldrijan et al., 2021).

In addition, structured microsites such as vegetation gaps with bare ground are important for species conservation in grasslands as they support the establishment of low-competitive plant species and provide unique microclimatic conditions necessary for the development of the immature stages of many invertebrate species (Streitberger et al., 2014). Likewise, areas of bare ground have been proven to be a crucial habitat feature for rare terrestrially foraging farmland birds in Central Europe (Tagmann-Ioset et al., 2012).

As it has been mentioned above, land-use intensification including the use of chemicals such as herbicides, pesticides and fertilizers has been constantly mentioned as an important threat to biodiversity. Nevertheless, the use of fertilizers appears to have different results between studies regarding their impacts on biodiversity. While numerous studies have demonstrated the negative effects of fertilization on species richness (Müller et al., 2016; John et al., 2016) another study proved that dominant species can be controlled in nutrient-limited grasslands by increasing nutrient levels in addition to mowing to manage competition for light (Pecháčková et al., 2010). Therefore, the impacts on biodiversity of the use of fertilizers may depend on the location and the soil nutrient level. Additionally, compared to chemical use, the reduction of pollution and green waste inputs into ditches is a management action mentioned but with very limited information about its impact on biodiversity.

Management actions regarding drainage in the SPIES tool include blocking or removing drainage ditches or reducing the intensity, installing or maintaining subsurface drains and installing or maintaining Sustainable Drainage Systems (SuDS). Although the potential outputs defer between studies, drainage seems to be a relevant feature to be analysed for maintaining habitats and biodiversity. A study made in French grasslands argued and proved that maintaining or enhancing the hydrological functioning of ecosystems is even more important than setting rules about when to cut grass and how much fertiliser to use in flooded naturally nutrient-rich meadows (Lafage & Pétillon, 2016). Meanwhile, in riverine fens in north-eastern Germany, a study showed that drained, intensive grassland was unsuitable for preserving fen-specific communities while moist meadows with extensive management retained a great number of threatened species (Görn et al., 2014). Additionally, it has been demonstrated that open drainage ditches of any size, including canalised former streams, are an important ecological component of the landscape heterogeneity of many countries (Marja et al., 2013). Hence, a study comparing populations of farmland birds in Finland proved that fields under open drainage provide higher habitat value in comparison to subsurface drainage (Marja et al., 2013).

2.3.4 Habitats

Management actions related to the creation, installation, or maintenance of habitats, either natural or artificial, normally have the intention to protect or restore certain species and support biodiversity. Nonetheless, understanding the true effects of each of these practices is crucial, since, while they may be beneficial in some circumstances, they may have a negative or no effect in others. Installation as well as maintenance procedures of bird boxes, for instance, have been found to benefit some species of birds but not have effects on other species (Ekner-Grzyb et al., 2014; von Post & Smith, 2015; Fargallo et al., 2001).

Furthermore, a study carried out on managed wet grasslands in eastern England proved that wet features could support a greater abundance of invertebrates and, in turn, support birds (Eglington et al., 2010). Similar management actions to consider include connecting habitats and the installation, creation, and maintenance of bat boxes, beetle banks, artificial refugia, buffer zones, field margins, and set-aside areas.

Nonetheless, the installation or maintenance of beehives has been a topic of discussion regarding their impact on the conservation of wild bees and other pollinators (Hudewenz & Klein, 2013). Due to the contribution of honeybees to wildflower and crop pollination, beekeeping has traditionally been considered a sustainable practice; however, numerous studies in different European countries suggest that honeybees may compete with other pollinators for floral resources when introduced as non-native insects or in high densities (Torné-Noguera et al., 2016; Goulson & Sparrow, 2009).

Contrary to the debatable installation of beehives, several studies have shown that planting and maintaining wildflowers or nectar seed meadows improves biodiversity in intensively managed agricultural settings (Grass et al., 2016). Wildflowers not only support a diverse range of flower-visitor species, including bees, butterflies, and other pollinators (Meichtry-Stier et al., 2014;

Lebeau et al., 2016) but have also been proven to benefit other species. For instance, a study on a Swiss arable landscape demonstrated that wildflower areas and semi-natural habitats strongly enhance the number of birds and hares (Meichtry-Stier et al., 2014).

2.3.5 Trees and hedges

It is widely acknowledged that trees provide several ecosystem services, such as carbon sequestration, air quality management, climate regulation and food provision. Therefore, planting and maintaining trees, hedgerows or shelterbelts has been considered a sustainable practice. In Europe, for instance, hedgerows constitute a significant proportion of semi-natural habitat patches in modern agricultural landscapes (Facey et al., 2014).

Moreover, hedgerows in agricultural areas provide important nesting, feeding, and sheltering sites for birds, serve as essential habitats for invertebrates, and their creation may be essential for enhancing native pollinator abundance and diversity, and for providing pollination services to adjacent crops (Batáry et al., 2010; Facey et al., 2014; Morandin & Kremen, 2013)

Due to the importance of trees in nature, their management could have a significant impact on biodiversity conservation and restoration. Therefore, distinct management actions such as allowing trees to grow in hedgerows, cutting hedges in winter, maintaining low hedges, and reducing hedge-cutting frequency to once every two years have been frequently discussed by researchers and should be evaluated to ensure positive outcomes.

3 METHODOLOGY

This section explains the methodology and the manner in which it was utilized to find connections between the site characteristics and management actions to enhance biodiversity.

3.1 Selection of methodology

According to Creswell (2014), the research methods and research designs that researchers use to address their research questions are significantly influenced by the philosophical worldview proposed in the study. The philosophical worldviews are explained as beliefs and orientations that the researcher brings to the study; four that are widely discussed are postpositivism, constructivism, transformative, and pragmatism (Creswell, 2014). This study presents a pragmatic worldview, which emerges from actions, situations, and consequences, and which, rather than focusing on methods, emphasizes the research problem and employs different approaches to understand it (Rossman & Wilson, 1985; Creswell 2014).

The quantitative research approach collects and analyses numerical data, whereas the qualitative research approach explores and understands complex phenomena using non-numerical data. In line with the pragmatic worldview of this study, the mix methods approach combines qualitative and quantitative approaches to provide a comprehensive analysis of the research problem and enhance each approach's strengths while limiting its flaws (Creswell & Plano Clark, 2018; Creswell, 2014). A mixed methods approach was chosen for this study since collecting data in various forms was necessary at different stages of the research (observations, site characteristics data package, and questionnaires completed by experts providing both numerical and textual answers). Moreover, qualitative, or quantitative data alone would be insufficient for achieving comprehensive results. Creswell (2014) discusses various mixed-methods research designs, such as convergent parallel, explanatory sequential, and exploratory sequential designs. From these, this study is classified as convergent parallel mixed methods, as quantitative and qualitative data are collected roughly at the same time, and the information is afterwards integrated into the interpretation of the overall results.

For this study, three different PV Parks in the Czech Republic managed by *the company* were selected as study subjects (*see Section 4*). The sites were selected considering their proximity and prioritizing differences in infrastructure, size, surroundings, and current management actions employed. After the selection of the study subjects, a site visit to each of them was performed. The purpose of the site visits was to collect data regarding the characteristics of each of the PV parks chosen, as well as the current and previous management actions taken at each location (*see Sections 3.2.1*). Textual, numerical, and photographic data were collected during the site visits to document the PV Park in as much detail as possible so that the experts could subsequently relate its characteristics to the management actions' impacts on biodiversity.

The data collected during the site visits together with maps, digital drawings and additional secondary sourced data were merged into an organized data package *(see Sections 3.2.2)* which was shared with the experts to complete a questionnaire. Furthermore, the questionnaire that the experts completed included opened-ended and closed-ended questions, that were required to be answered considering the information provided in the data package *(see Sections 3.2.3)*. More information on the selection of participants and the research tools and their implementation is provided in the following sections.

3.2 Research instrument

3.2.1 Site visits

The visits by the researcher to the three PV Parks took place on the same day in early August, 2022, accompanied by personnel responsible for the facilities' management. Data collection in each of the site visits followed a predetermined format, which comprised five major sections: Land use and structure, Management Actions, Local Environment, Physical Geography, and Immediate Surroundings. Each of the sections included variables that could be asked (A), observed (O), photographed (P) and/ or measured (M). The format was filled out for each of the PV Parks during the site visit.

Category	Action	Variable	Site 1 / Site 2 / Site 3
Land use and structure	M	Distance between pannels	*Number in meters*
Management Actions	A, O, P	Install/ maintain beehives	*Notes from answers and observations*
Local environment	A, O, P	Flora inside the site	*Notes from answers and observations*
Physical geography	A, O, P	Lakes, rivers, streams, or swamps nearby	*Notes from answers and observations*
Immediate surroundings	A, O, P	Urban areas around	*Notes from answers and observations*

TABLE 3: SITE VISIT DATA COLLECTION FORMAT.

The variables in the Management Actions section contained all the Management Actions assessed by the SPIES tool. The team that attended the site visit answered specific inquiries and provided details regarding the current and previous management actions conducted on each site. Additionally, photographs and notes from the variables in the site visit format were collected during the visit to later be organized and complemented with the following data collection tool.

The site visits were performed to share information about the sites with experts in different parts of Europe. Apart from reducing travel costs and related emissions, compared to the experts visiting the site individually, this approach allows experts in different locations to analyse and compare site data more efficiently, with greater flexibility and sufficient time.

3.2.2 Site characteristics data packages (SCDP)

After the collection of site characteristic data during site visits, the data was organized and compiled in a spreadsheet divided into six major sections; 1) Land Use and Structure, 2) Location and Surroundings, 3) Climate and Geography, 4) Environment, 5) Protected Areas and 6) Management Actions *(see Table 4).* To complement the primary data sourced during the site visits, secondary sourced data was collected by desktop research. The SCDP created for each site includes data in the form of text, measurement, digital drawings, satellite images, maps, and photographs. The following table explains the data included in each section.

Section	Data
1) Land Use and Structure	• Size of the PV Park • Fence height and location • Panels type and size • Structures material • Satellite image of the site with additional drawings illustrating and displaying the measurement of the perimeter, the distribution of the panels, and the distances between the panels and the fence • Technical drawing illustrating and displaying the measurements of the panels' structure and the distances between panels • Photographs taken during the site visit showing the panels' distribution, the areas between the panels, the fence and empty areas inside the site
2) Location and Surroundings	• Coordinates of the PV Park • Region and district where the site is located • Information about the site's immediate surroundings • Satellite images of the location at various distances (500m, 2km, 10km, 20km) • Photographs taken during the site visit showing the immediate surroundings of the PV Park

3) Climate and Geography	• Climate Region • Landforms inside the site location • Mean monthly temperatures °C (2000-2019) • Waterbodies nearby their distance from the site • Relief of the terrain • Altitude (meters above the sea level) • Possible Natural Hazards
4) Environment	• Land cover inside and around the site • Type of soils inside the site and its characteristics • Soil PH (range of measurements from samples taken in different parts of the site during the site visit with two different non-professional soil PH meters) • Soil aspect (color and texture observed during the site visit) • Details about flora observed during the site visit • Information about trees inside or around the park • Fauna observed in the last 2 years • Maps at various distances illustrating 1) Soil groups, 2) Terrestrial ecosystems and 3) Land Cover inside the site and around it • Photographs taken during the site visit showing flora and fauna of different parts of the site
5) Protected Areas	• A list of 10 PAs with a maximum of 14 km distance from the site, including for each PA: - Complete Name - Distance from the PV Park - If the PA is designated by Natura 2000 Habitats Directive, Natura 2000 Birds Directive or is a Nationally Designated Area - List of protected species - Groups of species and number of species per group - Name and area of protected habitats • Maps at various distances (from 2km to 30km) illustrating 1) Natura 2000 Birds Directive and Habitat Directive PA and 2) Nationally designated PA
6) Management Actions	• Photographs taken during the site visit related to the management actions employed in the site • Specific details regarding current and previous MA employed in the site (this information was later displayed in the Questionnaire sheet *(See Section 3.2.3))*

TABLE 4: DATA DISPLAYED IN EACH SITE CHARACTERISTICS DATA PACKAGE (SCDP).

Regarding the maps presented in sections 4) Environment and 5) Protected Areas, geodata from the European Environmental Agency website and ArcGIS workspace (EEA, 2021; EEA, 2022; European Space Agency & Esri, 2022; USGS et al., 2020; Soil Grids Organization & Esri, 2021) were collected and processed using the geographic information system software QGIS and ArcGIS Online. Additionally, satellite images in the SCDP were collected from Google Satellite in QGIS software and were processed in a similar way as the technical digital drawings using Adobe Illustrator. Moreover, the data about the PAs were collected from the European Nature Information System (EEA, n.d.).

3.2.3 Questionnaire

The data packages described so far were designed to capture and illustrate information about each PV park so that it could be shared with experts, who were required to fill out questionnaires based on the site-specific information provided. The main purpose of the questionnaires is to evaluate and understand the biodiversity-related impacts of management actions (MA) that could be or have been implemented at each PV Park.

After deciding to participate in the study, each of the experts received three independent Excel files, each file pertaining to one of the three sites selected for this study. Each file that was sent to the experts contained three sheets: 1) an introductory page with instructions; 2) a sheet presenting data on the specific solar park (the SCDP); and 3) a questionnaire which assesses the use of various management actions on that site. It is important to highlight that sheet number 3, which contains the questionnaire, also contains notes regarding current and previous MA employed on the site or details that could be relevant for the evaluation of the management actions. In completing the questionnaires, experts were asked to consider all the information presented in sheet number 2 (SCDP) and the notes provided in the first column of sheet number 3.

The questionnaire includes all the Management Actions included in the SPIES tool divided into seven categories: Grazing, Mowing, Drainage, Habitats, Pollution and Chemicals, Soil, and Trees and Hedges. For each MA, experts were required to evaluate the biodiversity-related impact, explain their evaluation, and mentioned the site characteristics that were relevant to their evaluation.

Column A	Column B	Columns C to G					Columns H to L					Column M	Column N
CATEGORY AND NOTES	**MANAGEMENT ACTIONS**	**BIODIVERSITY IMPACT EVALUATION**										**EXPLAIN IMPACT EVALUATION**	**RELEVANT SITE CHARACTERISTICS**
		ON-SITE					**OVERALL**						
		--	-	N	+	++	--	-	N	+	++		
CATEGORY 1 *Notes:*	**Management action 1**												
	Management action 2												

FIGURE 4: QUESTIONNAIRE EXAMPLE.

Following the visual example of the questionnaire (*see Figure 4*), Column A provided the respective MA categories and provided notes regarding the management actions currently and/or previously practised inside the site and/or additional details not mentioned in sheet number 2 (SCDP). Column B displayed the specific management action to be evaluated, as taken from SPIES. Columns C to G were used to evaluate the impact of the respective management action in terms of its effect on biodiversity inside the PV park. For this, experts chose one of the five options (-- strong negative impact, - weak negative impact, N neutral impact, + weak positive impact, ++ strong positive impact) by placing “1” in the chosen column. Marked in the same way but with a different purpose, Columns H to L were used to evaluate the broader biodiversity impacts of each management action (i.e., an overall assessment which takes into account not only the biodiversity impacts on the site but also the range of positive and negative biodiversity impacts that might result beyond the boundaries of the PV park). The two different assessments of biodiversity-related impacts were meant to identify whether the MA in question might have differentiated impacts within the park vs beyond its boundaries, arising, for example, through positive feedback loops or, conversely, through the displacement of negative impacts. After evaluating the impact on biodiversity both on-site and overall, the experts were required to explain (in Column M) the assessments provided and (in Column N) specify which characteristics of the PV Park were relevant for their evaluation. In cases where the management action to be evaluated was not applicable to the site, such as "ceasing grazing" on sites that are not presently grazed, experts were asked to assume that the management action was applicable.

3.3 Sampling of Experts

To select experts to be part of the study, a list of potential experts and their contact details was compiled as the sampling frame, from which a purposive sampling technique was applied to identify the most suitable candidates according to their qualifications and experience. Initially, a systematic search for experts in the field of biodiversity and/ or biodiversity in solar parks was conducted using LinkedIn and university websites as the main sources. On LinkedIn, specific search terms such as "biologist", "ecologist", “systemic ecology”, "biodiversity" and “biodiversity in solar parks” were used, with a focus on users located or with experience in the Czech Republic and European countries. This allowed for the investigation of the professional profiles of specialists working in academia, research institutions, or the private sector who possess the necessary expertise and knowledge regarding the research topic. In addition, extensive research was conducted on university websites, mainly on Lancaster University, which is recognised for the development of SPIES decision-support tool, and Masaryk University in Brno, which is located in the region where the PV parks are located. These university websites offered access to faculty directories, research centres, and departmental webpages, making it easier to identify specialists appropriate for this research topic.

Experts that decided to participate in this study were required to sign an NDA in order to protect sensitive data from *the company* that was shared with them in the Site Characteristics Data

Packages. For this and the complexity of the study, a redacted version of an Excel file for one PV park was attached when contacting the experts so that the experts could properly understand the nature of the assignment and consider their participation in the study.

The largest interest of the experts was observed in the United Kingdom, mostly between professors related to the SPIES tool, however, as the research intended to include experts with different experiences, knowledge, and background to make the study as objective as possible, only one of the selected experts was from the UK and had deep knowledge about SPIES tool. In addition, two experts from the region of the Czech Republic where the sites are located, along with one expert from Germany and one from Romania, decided to participate in the research *(see Table 5).*

	COUNTRY	ACADEMIC EXPERIENCE	ADDITIONAL EXPERIENCE
Expert 1	United Kingdom	- BSc in Ecology and Conservation - MSc in Biodiversity and Conservation	PhD student exploring the potential of solar parks to enhance pollinator biodiversity.
Expert 2	Germany	- BSc in Zoology/ Animal Biology - MSc in Wildlife Management and Conservation - PhD in Ecology	Global Biodiversity and Natural Resources Senior Manager of multinational corporation.
Expert 3	Czech Republic	- MSc in Systemic Biology and Ecology	Freelancer in biology and ecology services and environmental awareness lecturer.
Expert 4	Czech Republic	- BSc in Systemic Biology and Ecology - MSc in Ecology and Evolutionary Biology - PhD in Zoology	Specialist in the management, protection and restoration of natural biotopes in South Moravian.
Expert 5	Romania	- BSc in Zoology/ Animal Biology	Field biologist with a history of working in monitoring of biodiversity in Europe.

TABLE 5: LIST OF EXPERTS.

Despite the fact that the majority of experts had limited time to complete the three questionnaires, a greater number of experts than anticipated contributed to this study. However, the responses of one of the experts had to be excluded from the analysis due to inconsistencies with the provided data, and one of the experts was unable to complete the responses for Site 2 before the analysis was conducted. Finally, although 9 complete questionnaires were planned for this study (3 complete questionnaires per expert) the study incorporates 11 complete questionnaires from 4 experts.

3.4 Data analysis

With the broader research question "*What is the relationship between the characteristics of photovoltaic parks and biodiversity impacts of management actions?"*, the purpose of this study is to better understand the potential biodiversity impacts of each management action in each of the PV Park in order to;

- Find connections between site characteristics and potential biodiversity impacts of management actions.
- Compare the site-specific biodiversity impact evaluation of this study with SPIES results.
- Identify differences and similarities between the potential impact of the management actions on biodiversity inside and outside the sites.
- Identify the most beneficial and harmful management actions for each site.

Due to the nature of this study, convergent parallel mix methods, after the collection of both qualitative and quantitative data, the data were analysed separately and then merged to form a comprehensive interpretation. Moreover, the analysis as well as the interpretation of the results were performed per management action.

For the quantitative analysis, the results of the biodiversity impact evaluation from the experts for each management action split per site (on-site and overall) were compiled into descriptive tables and boxplot graphs. The descriptive tables include the number of responses, median, IQR, range, minimum value and maximum value. As the evaluations of on-site impacts were more prominent than the overall impact in most of the cases, the median on-site biodiversity impact evaluation values for each site and each management action were used as dependent variables in linear regression analyses to be predicted from the site characteristic variables that could be expressed as continuous quantitative data. These analyses were conducted to supplement and triangulate the experts' textual answers about relevant site characteristics.

Meanwhile, for the qualitative analysis, the explanations from the experts regarding their impact evaluation as well as their suggestions were combined and displayed for each management action per site. Additionally, the site characteristics of each site that the experts mentioned as relevant for their evaluation were listed for each management action. In sum, the interpretation of each management action includes:

- The experts' evaluations of the biodiversity impacts, expressed using boxplots and tables of descriptive statistics.

- Assessment of the positive, neutral, or negative range of median values and their consistency or inconsistency with SPIES.
- Detection of any systematic differences between on-site and overall evaluations, as well as differences across sites.
- A list of the site characteristics that the experts deemed relevant to their assessment.
- A list of site characteristics found to predict experts' assessments through regression.
- The general and per-site explanations of impacts and suggestions from the experts.

Lastly, boxplots related to the on-site evaluations of all the management actions per site were included to present the most beneficial and harmful management actions for each site.

4 CASE STUDY

This section intends to describe the region where the sites are located (South Moravia, Czech Republic), illustrate the characteristics of the sites and present the current and previous management actions employed at each site.

4.1 Biodiversity in South Moravia

The South Moravian Region, located in the southeast part of the Czech Republic, covers an area of 7,188 km^2, which accounts for 9% of the country's territory and is bordered by Austria, Slovakia and five other regions in the Czech Republic (Jihomoravský kraj, 2020). 60% of the region's land area is used for agriculture, with 83% of it being arable land, which is above average when compared to the Czech Republic. Cereals, rapeseed, and sugar beetroot are the primary crops grown in the region, while viticulture, fruit and vegetable growing also have a long tradition there (Jihomoravský kraj, 2020).

It has been reported that the region, along with the Central Bohemian and Moravian-Silesian regions, has the highest landscape fragmentation and the greatest loss of non-fragmented areas (Ministry of the Environment of the Czech Republic, 2014; CENIA, 2021). According to the Report on the Environment of the Czech Republic 2020, the increasing rate of fragmentation in Czech Republic is driven by continued urbanisation, particularly urban agglomerations, as well as the development of transport infrastructure. Furthermore, the country's agricultural birds and other species, which rely on environments with hedges, shrubs, field edges, and less intensively cultivated land, have declined (CBD, n.d.).

The South Moravian Region's climate is the highest of all regions in the Czech Republic with the average air temperature in 2019 being 10.6°C. Additionally, although 2019's total precipitation was slightly above average, the annual total precipitation of 587mm is the fourth lowest in the Czech Republic (Jihomoravský kraj, 2020). Moreover, according to the corresponding Report on the Environment of the Czech Republic, in 2020 South Moravia region was one of the regions with the highest values in average air temperature and average heat wave days while one of the lowest in soil moisture.

The Czech Republic boasts a relatively wide range of animal and plant species and habitats due to its location on the boundaries of four biogeographical sub provinces and its geological diversity. According to the Ministry of the Environment of the Czech Republic (2014), nearly 80,000 species have been recorded on its territory, with some areas such as south-eastern Moravia (especially in Pálava and the junction of the Morava and Dyje Rivers) having above-average species diversity. However, the distribution of species throughout the country is not even, and some are disappearing due to human activities. The International Union for Conservation of Nature (IUCN) Red List categories reveal that 19% of mammal species, 50% of bird species, 55% of reptile species, 43% of amphibian species, 40% of freshwater fish species, and 43% of vascular plant species in the country are threatened by extinction (CBD, n.d.).

The South Moravian Region's remarkable ecological variety is reflected in its 196 European important N2K sites, which account for about 8% of the region's territory (Jihomoravsk kraj, 2020). However, the region also faces challenges in maintaining its biodiversity. In the Czech Republic, from a geographical point of view, the highest number of endangered plant and animal species as well as of invasive species occur in southern Moravia (CENIA, 2021). In conclusion, the South Moravian Region of the Czech Republic boasts unique natural diversity, while facing challenges such as high landscape fragmentation, the extinction of various species, invasive species and climate-related hazards probably brought on by global warming.

4.2 Sites Characteristics

The sites in this study vary in size, location, layout, and panel technology *(see figure 5)*; however, there are still some similarities between them. All the plots where the PV Parks are installed are surrounded by a tall fence and are located close to arable lands.

- Site 1 *- Site 2* *- Site 3*

FIGURE 5: SITES LAYOUT.

Additionally, the mounting structures of sites 1 and 2 are made of concrete blocks, while site 3 is made of steel structures which are thinner and roughly double the height *(see figure 6).*

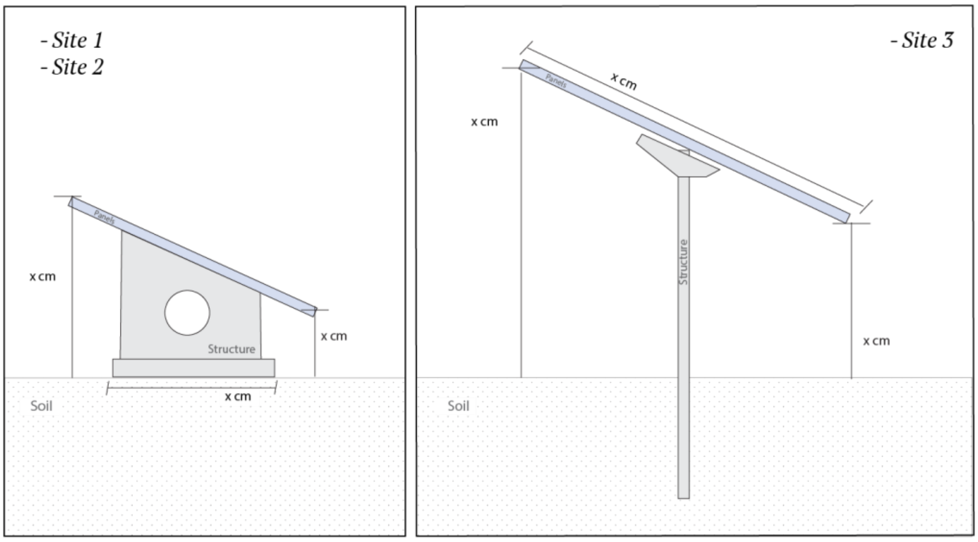


FIGURE 6: SITES STRUCTURES.

Contrarily to the sites' similarities in climate region and monthly mean temperature, the immediate surroundings of each site are quite different *(see figure 7).* Site 1 is surrounded by streets, residences, small industrial and agricultural areas, and woodland, and is located in a town that is inside a Nationally Designated Area. Site 2 is largely surrounded by agricultural areas with a few residences, whereas Site 3 is mostly surrounded by agricultural lands. None of the sites has trees within their fenced perimeters; nevertheless, trees outside site 1 occasionally cross the fence that surrounds the site, trees in the form of hedges border one side of the fence in site 2, and some trees were spotted outside site 3.

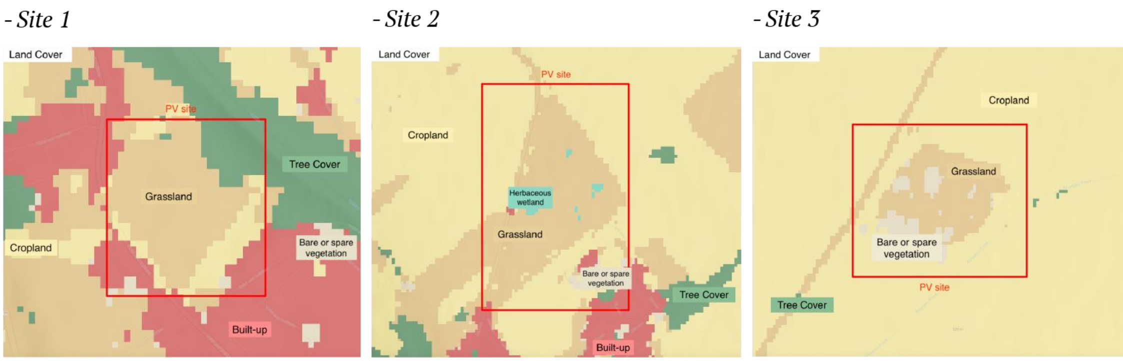


FIGURE 7: SITES' IMMEDIATE SURROUNDINGS.

During a visit to the sites in late summer 2022, the soil in all the sites appeared to be brown, dry, and compacted, with Ph values ranging from slightly acidic to neutral *(see Table 6).* Moreover, the soils where the sites are located are classified as Cambisols "Soils with a clay-enriched subsoil with wigh base status and high-activity clay" and Luvisols "Moderately developed soils in relatively young soils or soils with little or no profile development" (Esri et. al, 2021).

	Site 1	Site 2	Site 3
Size of the site	1.8 ha	5.8 ha	7.5 ha
Structure material	Concrete blocks	Concrete blocks	Steel structure
District	Hodonin	Breclav	Brno-venkov
Immediate surroundings	Houses, woodland, agricultural and industrial areas, protected areas and few roads	Agricultural areas, protected areas, few roads, few residence areas, and trees around the entrance	Mostly agricultural areas, few roads, and trees
Climate Region	Cool Temperate Moist	Cool Temperate Moist	Cool Temperate Moist
Landforms	Mountains	Plains	Hills
Hydrography	Next to a river which looks dry and full of grass and herbs	Around 500m from a lake	Around 8km from a reservoir
Relief of terrain	W slope (3°)	flat	flat
Altitude (m.a.s.)	301	173	313
Soil Group	Cambisols	Luvisols and Cambisols	Luvisols
Soil PH	Between 6.7 and 7	Between 6 and 6.9	Between 6 and 6.75
Flora (observed in august 2022)	Grass, herbs and many flowers.	Grass, herbs and almost no flowers. Large areas with dry vegetation.	Grass, herbs and almost no flowers.

TABLE 6: SITES CHARACTERISTICS.

The vegetation observed during the visit differed noticeably between locations. Site 1 was covered with various herbs, grasses, and flowers of multiple shapes, colours and sizes; some of the flowers observed were white, yellow, purple, and pink *(see figure 8).* In terms of variety and proportional quantity, Site 2 and Site 3 were covered with less vegetation than Site 1. Still, Site 2 appeared to have a slightly greater proportional quantity of flowers than Site 3, which was primarily covered by grass and herbs. Besides their differences, all the sites revealed areas under the panels with significantly less vegetation, most likely as a result of the previous use of herbicides. Additionally, all sites had some areas with spare vegetation or bare ground. Apart from the areas affected by the previous use of herbicides, during the site visit, dried or dead vegetation was mostly observed in the larger empty areas which were not covered by panels, trees, or infrastructure shadows.

Regarding the fauna within the locations, company personnel reported seeing rabbits, lizards, and mice in all the sites. During the site visit, a greater number of insects were spotted at Site 1 *(see figure 8)* and all the sites had some holes that may have been produced by rodents.

FIGURE 8: SITES VEGETATION OBSERVED DURING SITE VISIT.

Research on the protected areas included in the Natura 2000 network and the Common Database on Designated Areas (CDDA) around the sites was done in order to gain a greater understanding of the biodiversity involved. This information was also shared with the experts.

The CDDA and NATURA 2000 are two key tools for biodiversity conservation and protected areas in Europe. The CDDA keeps a comprehensive inventory of nationally designated protected areas across the European Union, and it is currently an agreed-upon yearly Eionet core data flow managed by the European Environment Agency (EEA, 2021; EEA, n.d.). On the other hand, NATURA 2000 is an ecological network of sites designated under the Birds Directive and Habitats Directive to protect Europe's most valuable and threatened species and habitats (EC, n.d.; EEA, n.d.). Because Natura 2000 is the world's largest coordinated network of protected areas, and it also contains detailed information, this section will briefly present the nearest N2K protected areas from each PV park of this research *(see Tables 7, 8 and 9).*

As it is displayed in *Table 7,* there are three PAs from N2K that are less than one kilometre from Site 1. Actually, this site is located inside Bílé Karpaty nationally designated area from CDDA inventory but outside of the designated area under N2K. Flowering plants, invertebrates and amphibians are the main groups of species that are protected in PAs nearby. Moreover, the closest PA from Birds Directive is “Bzenecká Doubrava - Strážnické Pomoraví” around 14 km away from Site 1 and it protects 6 different species of Birds.

Site 1 - Closest PAs from N2K					
Distance from site	**PA name and size**	**Directive**	**Protected Species**	**Species group and number**	**Protected Habitat**
350m	Bílé Karpaty (20043 ha)	Habitats Directive	Cypripedium calceolus, Klasea lycopifolia, Liparis loeselii, Carabus variolosus, Colias myrmidone (Danube Clouded Yellow), Cucujus cinnaberinus, Eriogaster catax, Euplagia quadripunctaria, Lycaena dispar (Large Copper), Phengaris nausithous, Phengaris teleius, Vertigo angustior, Vertigo moulinsiana	Flowering Plants (3), Invertebrates (10)	Hard oligo-mesotrophic waters with benthic vegetation of Chara spp **(0.02 ha),** Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites)**(879.2 ha),** Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites)**(667.65 ha),** Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae) **(45.87 ha),** Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels **(18.64 ha),** Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)**(1789.82 ha),** Petrifying springs with tufa formation (Cratoneurion) **(1.97ha)**, Alkaline fens **(0.48 ha)**, Luzulo-Fagetum beech forests **(101.87 ha),** Asperulo-Fagetum beech forests **(4913.1 ha),** Galio-Carpinetum oak-hornbeam forests **(2357.2 ha),** Tilio-Acerion forests of slopes, screes and ravines **(124.75ha),** Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)**(93.02 ha),** Pannonic woods with Quercus petraea and Carpinus betulus **(51.62 ha),** Euro-Siberian steppic woods with Quercus spp **(79.14 ha)**
773m	Velický hliník (4.87ha)	Habitats Directive	Bombina variegata - Yellow-bellied toad	Amphibians (1)	N/A
840m	Nad Vápenkou (0.54 ha)	Habitats Directive	Pulsatilla grandis	Flowering Plants (1)	N/A

TABLE 7: THREE CLOSEST N2K PAS FROM SITE 1.

Of the three sites, Site 2 is the one closest to PAs focused on birds. The closest PA under Birds Directive is Pálava, while the second closest is more than 5 km away from the site. Additionally, as Site 1, the three closest N2K PAs are less than one kilometre away. Furthermore, the predominant protected species from the N2K PAs around Site 2 are birds, invertebrates, and mammals.

Site 2 closest PAs from N2K					
Distance from the site	**PA name**	**Directive**	**Protected Species**	**Species group and number**	**Protected Habitat**
17m	Pálava (8539.38 ha)	Birds Directive	Ciconia ciconia (White Stork), Dendrocopos medius (Middle Spotted Woodpecker), Dendrocopos syriacus (Syrian Woodpecker), Ficedula albicollis (Collared Flycatcher), Haliaeetus	Birds (8)	N/A

			albicilla (White-tailed Eagle), Lanius collurio (Red-backed Shrike), Pernis apivorus (Honey Buzzard), Sylvia nisoria (Barred Warble)		
520m	Milovický les (2443.20 ha)	Habitats Directive	Eriogaster catax, Euplagia quadripunctaria, Lucanus cervus (Stag Beetle), Barbastella barbastellus (Barbastelle), Myotis bechsteinii (Bechstein's bat)	Invertebrates (3), Mammals (2)	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites)**(17.70 ha)**, Sub-Pannonic steppic grasslands **(5.62 ha)**, Pannonic woods with Quercus petraea and Carpinus betulus **(945.66 ha),** Pannonian woods with Quercus pubescens (50.86 ha), Euro-Siberian steppic woods with Quercus spp **(752.15 ha)**
956m	Niva Dyje (3249.04 ha)	Habitats Directive	Bombina bombina (Fire-bellied toad), Misgurnus fossilis (Mud loach), Rhodeus amarus, Anisus vorticulus, Cerambyx cerdo, Cucujus cinnaberinus, Lucanus cervus (Stag Beetle), Lycaena dispar (Large Copper), Osmoderma eremita, Castor fiber (European beaver), Rhinolophus hipposideros (Lesser horseshoe bat)	Amphibians (1), Fishes (2), Invertebrates (6), Mammals (2)	Natural eutrophic lakes with Magnopotamion or Hydrocharition -type vegetation **(8.21 ha),** Alluvial meadows of river valleys of the Cnidion dubii **(293.84 ha)**, Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis) **(48.72 ha),** Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae) **(70.73 ha),** Riparian mixed forests of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia, along the great rivers (Ulmenion minoris) **(1337.56 ha)**

TABLE 8: THREE CLOSEST N2K PAS FROM SITE 2.

Differently from the other PV Parks, there is no PA from N2K or CDDA within a one-kilometre distance from Site 3. In fact, the closest nationally designated area is more than four kilometres away and the closest N2K PA is more than six kilometres away from Site 3. Nevertheless, the species that were mentioned the most by the nearest PAs were invertebrates and flowering plants.

Site 3 - Closest PAs from N2K					
Distance from the site	**PA name**	**Directive**	**Protected Species**	**Species group and number**	**Protected Habitat**
6.27km	Podkomorské lesy (567.05 ha)	Habitats Directive	Lucanus cervus (Stag Beetle)	Invertebrates (1)	N/A
6.53km	Bosonožský hájek (46.60 ha)	Habitats Directive	Cypripedium calceolus	Flowering plants (1)	Galio-Carpinetum oak-hornbeam forests **(36.12 ha)**
6.7km	Rozsypaná (11.95 ha)	Habitats Directive	N/A	N/A	Medio-European upland siliceous screes **(0.9 ha)**, Tilio-Acerion forests of slopes, screes and ravines **(6.95 ha)**

TABLE 9: THREE CLOSEST N2K PAS FROM SITE 3.

Their closeness to PAs, as well as the species and habitats that are protected, are some of the differences between the three sites. Among the nearest N2K PAs from all sites, a wide range of protected habitats were highlighted. In addition, the Stag Beetle (Lucanus cervus) was the species most often mentioned in all the N2K PAs reviewed.

4.3 Current Management Actions

In terms of grazing, Site 1 and Site 2 do not practice any grazing activities, while Site 3 has a current grazing intensity of 6.6 ewes per hectare, with a rotation of 14 days on the field and 14 days off the field, from April/May to October *(see Picture 1).*

To keep the vegetation around the panels under control, all sites need some mowing, and all of them employ a similar approach which is weather-dependent. In Site 1 and Site 2, mowing takes place three to four times a year between April and October, before the grass covers the panels. Mowing takes three to four days on average at these sites and is done using a tractor wherever feasible, but in areas where the tractor cannot access, the grass is cut by hand with trimmers or mower. At Site 3 mowing takes place where sheep are not grazing, also three to four times a year from April/ May onwards. While the cuts at each location are not perfectly uniform due to the diverse methods employed, in the three sites, mowing is done all at once.

Regarding other management actions mentioned in the SPIES tool, herbicides were formerly applied under the panels and around the fence at all locations, however, this practice was discontinued in 2021. With the exception of the previous usage of herbicides, none of the sites has altered the soil, no chemicals have been utilised and limited quantities of waste are generated on-site. Additionally, none of the sites has artificial drainage systems and no wet patches or standing water has been observed at any of the locations. Despite the fact that none of the sites has undertaken habitat-related measures, Site 1 frequently hosts a number of bees from a neighbouring beehive. Furthermore, as there are no trees or hedges inside any of the sites, no management action related has been employed.

In conclusion, the three PV sites share similarities in terms of management actions regarding mowing, drainage, habitats, pollution, chemicals, soil, trees and hedges. However, Site 3 is the only one that practices grazing activities with a rotation system for the sheep.

IMAGE 1: SHEEP GRAZING IN PV PARK.

5 RESULTS AND DISCUSSION

This section displays the merged interpretation of the results of both quantitative and qualitative analysis as explained in *section 3.4 Data Analysis*. The results are presented first by each management action, and then summarized in terms of the most desirable MAs per site.

5.1 Management Actions and Site Characteristics

5.1.1 Cease grazing if previously grazed

Figure 9 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral and negative evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more negative impact on biodiversity within the site than in the surrounding region.

The management action is perceived as less harmful to biodiversity on Site 3 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Cease grazing if previously grazed	Site 1: on-site	4	−1.000	0.500	2	-2	0
	Site 1: overall	4	0.000	0.500	2	-2	0
	Site 2: on-site	3	-1	1.000	2	-2	0
	Site 2: overall	3	-1	1.000	2	-2	0
	Site 3: on-site	4	−0.500	1.750	4	-2	2
	Site 3: overall	4	0.000	0.750	3	-1	2

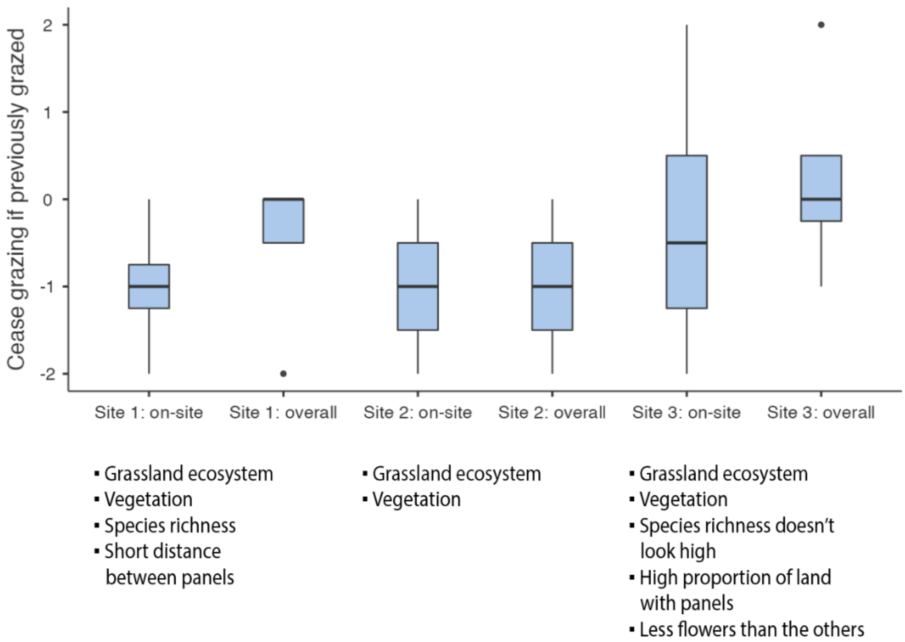


FIGURE 9: CEASING GRAZING - IMPACT PER SITE

In addition to the relevant site characteristics mentioned by the experts listed above, most experts mentioned that the impact of ceasing grazing would depend on the cutting regime that would replace it. Multiple times was mentioned that an absence of management or replacement of non-intensive grazing for more intensive management would negatively impact biodiversity. Moreover, experts mentioned that some management is required to ensure that aggressive species don't dominate, and the sward becomes ranked. Furthermore, experts repeatedly stated that extensive grazing is suitable and beneficial to the entire grassland ecosystem (flowers, insects, birds, etc..). Regarding the structures, it was mentioned that mowing when the panels are very close to each other or take most of the available land could be less efficient than grazing.

In the case of Site 3, the only one that is currently managed by sheep grazing, experts considered that immediate impacts of ceasing grazing might be beneficial as vegetation could establish, but over time a habitat potentially incompatible with a solar park might develop. According to the experts, because the species richness appears to be low at this site, it is unlikely that the cessation of grazing will have an effect on the overall biodiversity value.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Ceasing grazing if previously grazed", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Distance from a PA that protects amphibians (p=0.016, r2=0.999), whereby the positive estimate suggests that sites with longer distances from a PA that protects amphibians are associated with a more positive impact of this management action on biodiversity.
- Distance from a PA that protects invertebrates (p=0.016, r2=0.999), whereby the positive estimate suggests that sites with longer distances from a PA that protects invertebrates are associated with a more positive impact of this management action on biodiversity.
- Distance from the closest N2K PA (p=0.030, r2=0.998), whereby the positive estimate suggests that sites with longer distances from an N2K PA are associated with a more positive impact of this management action on biodiversity.
- Distance from the closest PA (p=0.002, r2=1), whereby the positive estimate suggests that sites with longer distances from a PA that protects amphibians are associated with a more positive impact of this management action on biodiversity.

Although these 4 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: grassland ecosystem, site vegetation, species richness, amount of flowers, distance between panels and proportion of land covered with panels.

5.1.2 Graze later in the year

Figure 10 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as less beneficial to biodiversity on Site 3 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

	sites	N	Median	IQR	Range	Minimum	Maximum
Graze later in the year	Site 1: on-site	4	1.000	0.500	2	0	2
	Site 1: overall	4	1.000	0.250	1	0	1
	Site 2: on-site	3	2	1.500	3	-1	2
	Site 2: overall	3	1	1.500	3	-1	2
	Site 3: on-site	4	1.000	2.250	3	-1	2
	Site 3: overall	4	0.500	1.500	3	-1	2

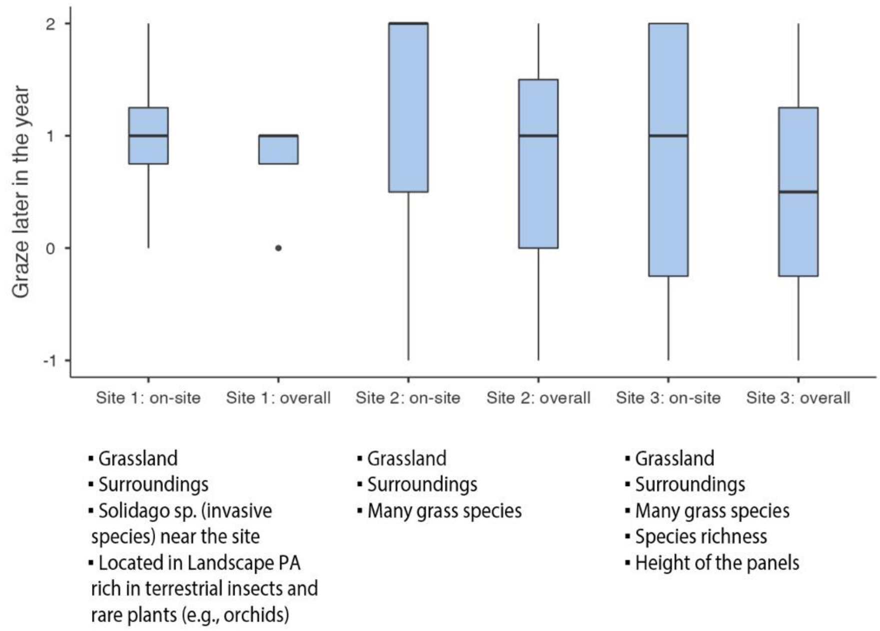


FIGURE 10: GRAZE LATER IN THE YEAR - IMPACT PER SITE

In general, experts mentioned that delaying grazing until later in the year would allow plant species to flower and set seed, and pollinators the opportunity to use any floral resources on the site during the spring/summer, positively impacting biodiversity inside the site and in the surroundings.

Regarding Site 1, experts mentioned that realising grazing from May to autumn would be more beneficial because this could: (1) create a mosaic habitat that could be very attractive for many species of Arthropoda, (2) reduce the invasive species near the site (Solidago sp.) and (3) offer an opportunity for rare plants on the PA where is located to occur on the site.

Site 2 and Site 3 were considered by the experts as sites with many grass species where grazing later in the year could be less suitable as this MA could support the dispersion of grasses. Nevertheless, in the case of Site 3, was considered beneficial with the current intensity to graze later in the year only in combination with improving sward diversity.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Graze later in the year", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Altitude (p=0.049, r2=0.994), whereby the negative estimate suggests that sites with higher altitudes are associated with a less positive impact of this management action on biodiversity.
- Area of the largest rectangular corridor (p=0.012, r2=1), whereby the positive estimate suggests that sites with larger rectangular areas without panels are associated with a more positive impact of this management action on biodiversity.

Although these 2 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: grassland ecosystem, amount of grass species, invasive species near the site, panels height, location in a protected area, surroundings and species richness.

5.1.3 Reduce grazing intensity if previously grazed

Figure 11 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as less beneficial to biodiversity on Site 1 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Reduce grazing intensity if previously grazed	Site 1: on-site	4	0.500	1.500	3	-1	2
	Site 1: overall	4	0.500	1.000	1	0	1
	Site 2: on-site	3	1	1.000	2	0	2
	Site 2: overall	3	1	0.500	1	0	1
	Site 3: on-site	4	1.000	0.500	2	0	2
	Site 3: overall	4	1.000	0.250	1	0	1

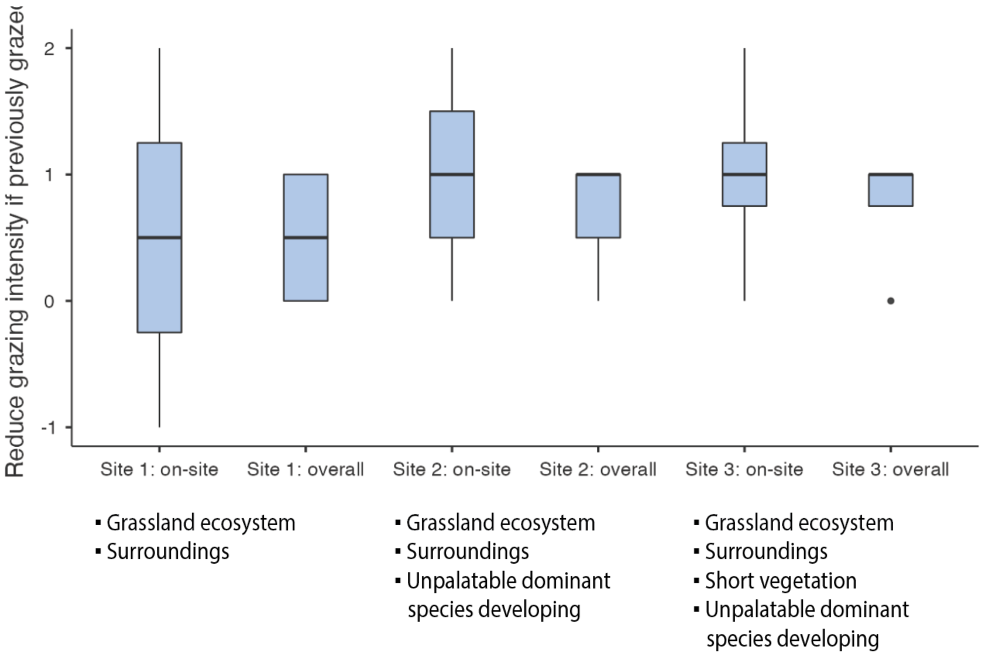


FIGURE 11: REDUCE GRAZING INTENSITY - IMPACT PER SITE

According to the experts, in general, reducing grazing intensity could allow more flowering plants to establish on the site, impacting biodiversity inside and outside the site. Furthermore, although specialists recommended intensities of 3 and 10 ewes per hectare, it was emphasised that future grazing intensities should be planned based on biodiversity monitoring.

In the case of Site 3, multiple times was suggested to reduce the grazing intensity (currently 6 ewes per hectare) to improve the heterogeneity of the site and therefore of the surrounding areas. In addition, suggestions for this site include keeping sheep off the solar park for longer periods (ideally most of spring/summer) and reducing the number of ewes per hectare to 3 ewes per hectare.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: grassland ecosystem, surroundings, development of unpalatable dominant species and vegetation height.

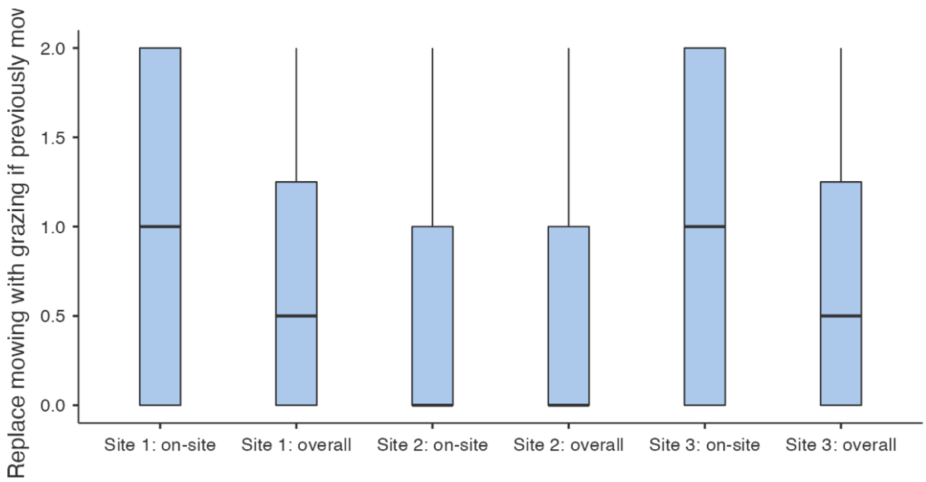
5.1.4 Replace mowing with grazing if previously mowed

Figure 12 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral and positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as less beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Replace mowing with grazing if previously mowed	Site 1: on-site	4	1.000	2.00	2	0	2
	Site 1: overall	4	0.500	1.25	2	0	2
	Site 2: on-site	3	0	1.00	2	0	2
	Site 2: overall	3	0	1.00	2	0	2
	Site 3: on-site	4	1.000	2.00	2	0	2
	Site 3: overall	4	0.500	1.25	2	0	2



Site 1:
- Grassland
- Surroundings
- Short distance between panels
- Panels closer to the ground
- Location

Site 2:
- Grassland
- Surroundings

Site 3:
- Grassland
- Surroundings
- Short vegetation
- High proportion of land with panels

FIGURE 12: REPLACE MOWING WITH GRAZING IF PREVIOUSLY MOWED - IMPACT PER SITE

According to the experts, determining whether grazing or mowing has a greater impact on biodiversity is complex, debatable, and depends on different factors such as the intensity and animals used.

In general, mowing was mentioned to have the benefit of allowing more control of the vegetation, offering different opportunities such as leaving certain areas of vegetation to grow taller, managing sites without fences and controlling weedy species that are not palatable to animals.

Moreover, it was mentioned that grazing could increase the nutrient loading due to the manure impact, therefore, mowing could be preferred in some locations if there is a high N in the soil.

Nevertheless, most of the experts agreed that grazing is generally preferred for biodiversity and some of the arguments mentioned were: (1) it could potentially create more variation in vegetation structure benefiting invertebrates, (2) it creates areas of bare ground, (3) it creates a mosaic structure of vegetation and thus a larger species pool, (4) it has the potential of changing the homogeneous are of PV sites to an island of biodiversity in the surrounding landscape, (5) it increases the number of insect and bird species on the managed site, (6) it is more gentle to all parts of the grassland ecosystem, (7) it could be more resource efficient in sites were panels take most of the available land, the panels are too close to each other and/or are closer to the ground.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Replace mowing with grazing if previously mowed", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Altitude (p=0.049, r2=0.994), whereby the positive estimate suggests that sites with higher altitudes are associated with a more positive impact of this management action on biodiversity.
- Area of the largest rectangular corridor (p=0.012, r2=1), whereby the negative estimate suggests that sites with larger rectangular areas without panels are associated with a less positive impact of this management action on biodiversity.

Although these 2 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: grassland ecosystem, surroundings, panels height, distance between panels, proportion of land covered with panels, vegetation height and soil nutrients (although no information about this was available).

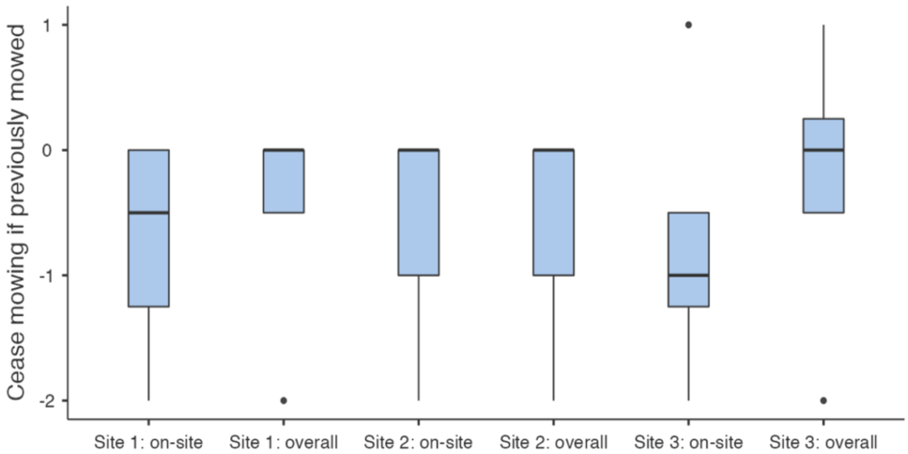
5.1.5 Cease mowing if previously mowed

Figure 13 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral and negative evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more negative impact on biodiversity within the site than in the surrounding region.

The management action is perceived as less harmful to biodiversity on Site 3 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Cease mowing if previously mowed	Site 1: on-site	4	−0.500	1.250	2	-2	0
	Site 1: overall	4	0.000	0.500	2	-2	0
	Site 2: on-site	3	0	1.000	2	-2	0
	Site 2: overall	3	0	1.000	2	-2	0
	Site 3: on-site	4	−1.000	0.750	3	-2	1
	Site 3: overall	4	0.000	0.750	3	-2	1



Site 1:
- Grassland
- Vegetation
- Presence of invasive species near the site
- Location
- Surroundings

Site 2:
- Grassland
- Vegetation

Site 3:
- Grassland
- Vegetation
- Species richness doen't look high
- Located in the middle of crop fields
- Available space for tractor mowing
- Climate and geography

FIGURE 13: CEASE MOWING IF PREVIOUSLY MOWED - IMPACT PER SITE

In addition to the relevant site characteristics mentioned by the experts listed above, most experts mentioned that the impact of ceasing mowing would depend on the cutting regime that would replace it. In general, it was mentioned that some management is required to prevent dominant species to take over, and the grassland goes rank in nature. Moreover, experts mentioned that as mowing increases the heterogeneity of the sites, it is an appropriate form of management.

In the case of Site 1, it was multiple times mentioned that this action would have a negative impact as it can cause the spread of invasive species. Additionally, a negative impact on rare plants and a positive impact on several insect species were pointed out.

For Sites 1 and 2, evaluating the suitability of introducing grazing animals was suggested as grazing was considered less invasive. However, in the case of Site 2 the current mowing regime was mentioned to be intensive and expensive, therefore an evaluation of the intensity and a review of current management in protected areas near the site was suggested.

Regarding Site 3, one of the experts considered that ceasing mowing could be beneficial as the site is already grazed and that a less intensive mowing regime might encourage vegetation and flowering plants to establish. However, other experts considered mowing an appropriate form of management. Because the site is surrounded by crop fields with probable high levels of pesticides a probable low level of biodiversity in general, was mentioned. Furthermore, because species richness doesn't look too high, it was mentioned that this management action is unlikely to impact the overall biodiversity value.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: grassland ecosystem, location, surroundings, presence of invasive species, vegetation, species richness inside the site and its surroundings, climate and geography.

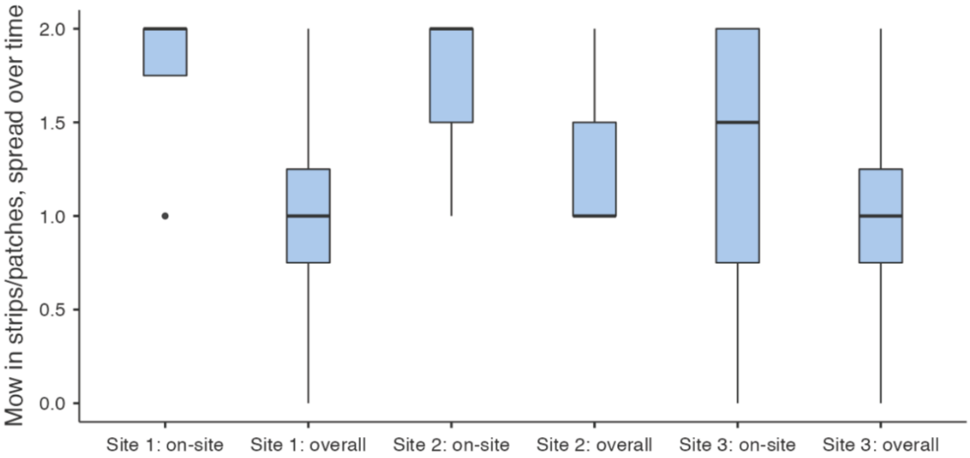
5.1.6 Mow in strips/patches, spread over time

Figure 14 presents the descriptive statistics for the experts’ evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as less beneficial to biodiversity on Site 3 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Mow in strips/patches, spread over time	Site 1: on-site	4	2.00	0.250	1	1	2
	Site 1: overall	4	1.00	0.500	2	0	2
	Site 2: on-site	3	2	0.500	1	1	2
	Site 2: overall	3	1	0.500	1	1	2
	Site 3: on-site	4	1.50	1.250	2	0	2
	Site 3: overall	4	1.00	0.500	2	0	2



- Grassland
- Surroundings
- A lot of space without
- panels in the margin areas
- Narrow gaps between rows of panels
- Location

- Grassland
- Surroundings
- A lot of space without
- panels in the margin area
- Narrow gaps between rows of panels
- Site layout with the vast majority of the site being covered in panels

- Grassland
- Surroundings
- A lot of space without panels in the margin areas and between rows of panels
- Not large enough areas of grassland
- Climate and geography

FIGURE 14: MOW IN STRIP/ PATCHES, SPREAD OVER TIME - IMPACT PER SITE

All of the experts agreed that this management action has, in general, a positive impact on biodiversity as it could: (1) create areas of vegetation with different structures beneficial to invertebrates with potential consequences for their predators e.g., birds/bats, (2) allow species in unmown areas to flower and set seed, (3) increase heterogeneity on the site benefiting plants and Arthropods, (4) allow higher vegetation that is an important cover and source of food for Arthropods and (5) change the homogenous area of PV site to an island of biodiversity in the surrounding landscape. Nevertheless, although some consider that all the sites have large enough areas for this management action to be suitable, others considered that the spaces available are not enough.

In addition, only for Site 2, it was mentioned that this management action could provide enough cover for ground-nesting birds. Meanwhile, in the case of Site 3, it was mentioned that the current grazing has a higher impact than this management action.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Mow in strips/patches, spread over time", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Distance from a PA that protects amphibians ($p=0.016$, $r2=0.999$), whereby the negative estimate suggests that sites with longer distances from a PA that protects amphibians are associated with a less positive impact of this management action on biodiversity.
- Distance from a PA that protects invertebrates ($p=0.016$, $r2=0.999$), whereby the negative estimate suggests that sites with longer distances from a PA that protects invertebrates are associated with a less positive impact of this management action on biodiversity.
- Distance from the closest N2K PA ($p=0.030$, $r2=0.998$), whereby the negative estimate suggests that sites with longer distances from an N2K PA are associated with a less positive impact of this management action on biodiversity.
- Distance from the closest PA ($p=0.002$, $r2=1$), whereby the negative estimate suggests that sites with longer distances from a PA that protects amphibians are associated with a less positive impact of this management action on biodiversity.

Although these 4 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: grassland ecosystem, surroundings, areas without panels, distance between panels, location, flora, climate and geography.

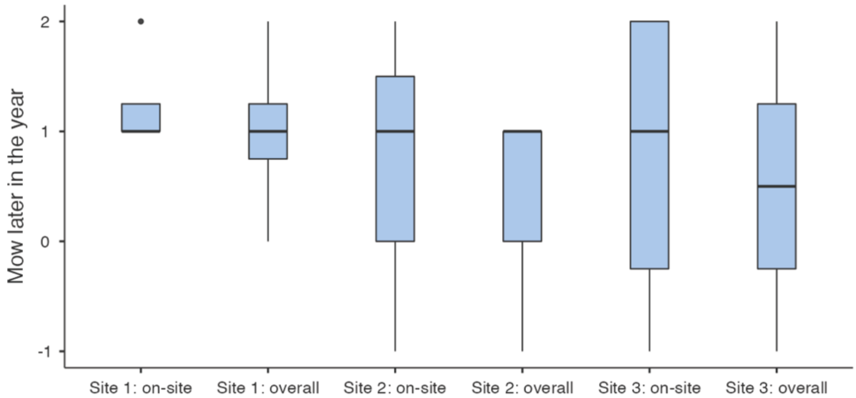
5.1.7 Mow later in the year

Figure 15 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 1 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Mow later in the year	Site 1: on-site	4	1.000	0.250	1	1	2
	Site 1: overall	4	1.000	0.500	2	0	2
	Site 2: on-site	3	1	1.500	3	-1	2
	Site 2: overall	3	1	1.000	2	-1	1
	Site 3: on-site	4	1.000	2.250	3	-1	2
	Site 3: overall	4	0.500	1.500	3	-1	2



- Grassland
- Surroundings
- Solar panels are low to the ground
- Solidago sp. (invasive species) near the site
- Location

- Grassland
- Surroundings
- Narrow strips between the panels rows
- Many grass species

- Grassland
- Surroundings
- Species richness
- Not large enough areas of grassland
- Many grass species
- Vegetation
- Climate and geography

FIGURE 15: MOW LATER IN THE YEAR - IMPACT PER SITE

It was multiple times mentioned by different experts for all the sites that this management action would be beneficial as it would allow flowering plants to flower and set seed, and that could benefit the organisms in the surroundings that utilise resources inside the boundary.

For Site 1 and Site 2 this MA was mentioned to have the possibility of providing nectar and pollen resource for pollinators. Moreover, for Site 2 and Site 3, this MA was considered less suitable as it can support the dispersion of grasses, in addition, it was explained that to increase biodiversity and support flowers, it is important to decrease the amount of grasses that produce seeds in summer.

In the case of Site 1 experts claimed that this management action has the potential to reduce Solidago sp. invasive species and that at least outside the concrete blocks it can help to develop rarer plant species as well as let the insect complete the life cycle. Meanwhile, for Site 2, it was mentioned that this MA should be done to enable a habitat for ground-nesting birds. Lastly, for Site 3 this MA was suggested in combination with actions to increase species richness, e.g., use of green hay, or seeding.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: grassland ecosystem, surroundings, panels height, invasive species near the site, distance between panels, amount of grass species, species richness, vegetation, location, climate and geography.

5.1.8 Reduce mowing regime to once a year

Figure 16 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 3 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Reduce mowing regime to once a year	Site 1: on-site	4	2.00	0.750	3	-1	2
	Site 1: overall	4	1.00	0.750	3	-1	2
	Site 2: on-site	3	1	0.500	1	1	2
	Site 2: overall	3	1	0.000	0	1	1
	Site 3: on-site	4	1.50	1.000	1	1	2
	Site 3: overall	4	1.00	0.500	2	0	2

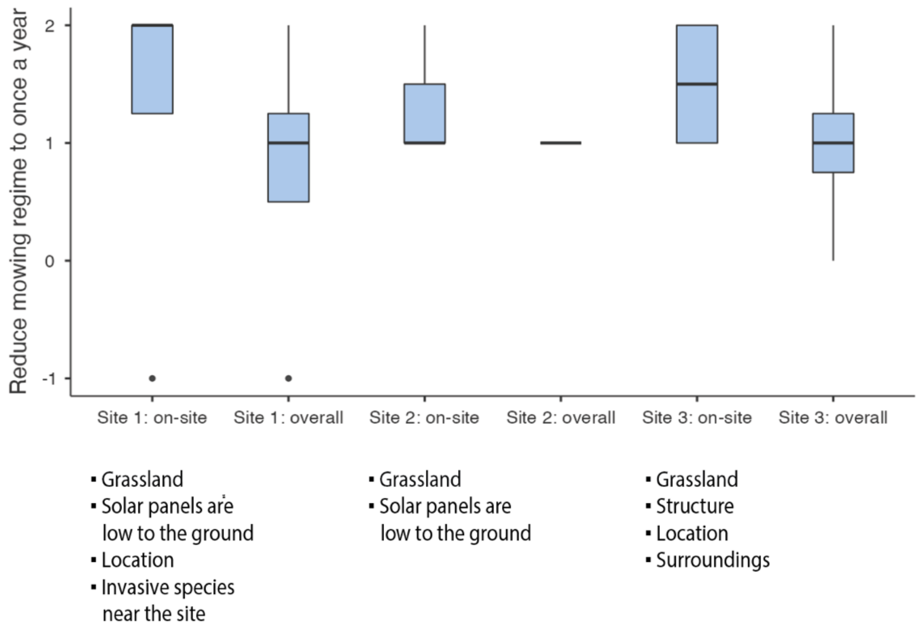


FIGURE 16: REDUCE MOWING REGIME TO ONCE A YEAR - IMPACT PER SITE

In general, experts mentioned that this MA would allow areas of taller vegetation to establish benefiting a range of groups including pollinators, and small mammals and that it would allow all grassland areas time to flower and set seed. However, some experts shared their concerns with Site 1 and Site 2 as the panels are low to the ground and vegetation could cover them.

Mowing in Site 2 was suggested to be done once or twice because of its positive effect on vegetation and mosaic habitat and once in late July at the earliest. Moreover, while mowing for Site 1 was suggested to be done at least twice a year and later in the season before the spreading of invasive species seeds, mowing for Site 3 was suggested to be planned once a year maximum because if not the site would be very homogenous and with low biodiversity.

Furthermore, for Site 1 and Site 3, this MA was suggested to be done in combination with actions to increase species richness, e.g., use of green hay, or seeding. Also, for these sites was mentioned that at least outside of the concrete blocks or outside of the panels this MA can help to develop rarer plant species as well as let the insect complete their life cycle.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: grassland ecosystem, surroundings, panels height, location and invasive species near the site.

5.1.9 Remove mowing clippings from semi-natural grassland

Figure 17 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is inconsistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 3 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Remove mowing clippings from semi-natural grassland	Site 1: on-site	4	1.00	0.000	0	1	1
	Site 1: overall	4	1.00	0.250	1	0	1
	Site 2: on-site	3	1	0.500	1	1	2
	Site 2: overall	3	1	0.000	0	1	1
	Site 3: on-site	4	1.50	1.000	1	1	2
	Site 3: overall	4	1.00	0.500	2	0	2

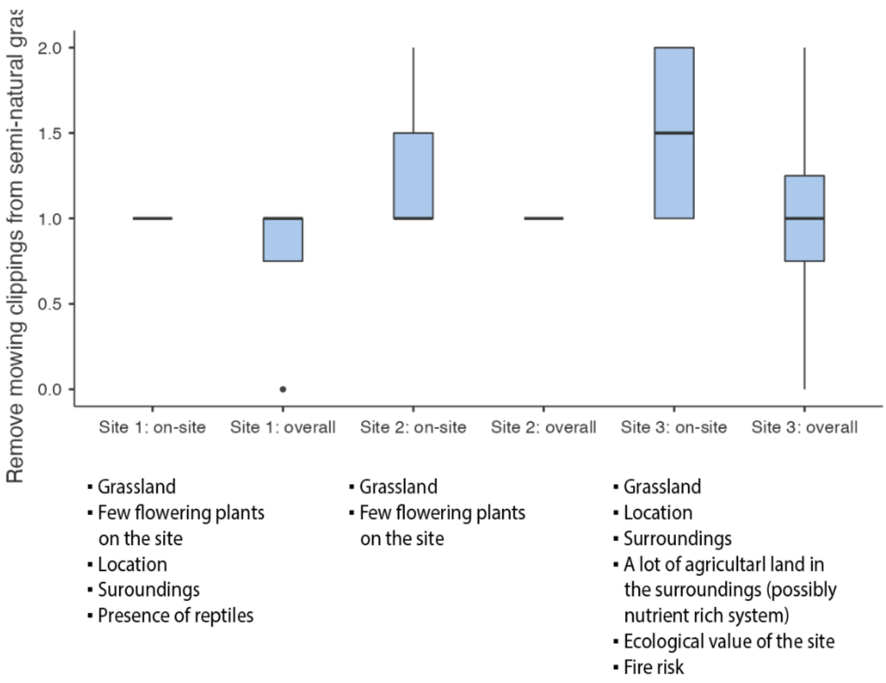


FIGURE 17: REMOVE MOWING CLIPPINGS FROM SEMI-NATURAL GRASSLAND - IMPACT PER SITE

According to the experts, generally, removing clippings from semi-natural grassland is important as it prevents eutrophication/ excess of nutrients entering the soil/ increasing the nutrient value of the soil. Additionally, experts mentioned that not removing the mowing clippings from semi-natural grassland could favour dominant/ aggressive generalist species and reduce the species richness and overall biodiversity value of the site.

For Site 1 and Site 3, it was mentioned that this MA could raise the quality of flowers. Moreover, for Site 1 it was suggested to pile some of the clippings into a heap to make a compost heap, which can be a useful feature for reptiles. In addition, for Site 3 was mentioned that although mean summer temperatures do not get too high if dry grass clippings are left, this could provide a potential fire risk.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Remove mowing clippings from semi-natural grassland", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Distance from a PA that protects amphibians ($p=0.016$, $r2=0.999$), whereby the positive estimate suggests that sites with longer distances from a PA that protects amphibians are associated with a more positive impact of this management action on biodiversity.
- Distance from a PA that protects invertebrates ($p=0.016$, $r2=0.999$), whereby the positive estimate suggests that sites with longer distances from a PA that protects invertebrates are associated with a more positive impact of this management action on biodiversity.
- Distance from the closest N2K PA ($p=0.030$, $r2=0.998$), whereby the positive estimate suggests that sites with longer distances from a N2K PA are associated with a more positive impact of this management action on biodiversity.
- Distance from the closest PA ($p=0.002$, $r2=1$), whereby the positive estimate suggests that sites with longer distances from a PA that protects amphibians are associated with a more positive impact of this management action on biodiversity.

Although these 4 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: grassland ecosystem, surroundings, amount of flowering plants in the site, presence of reptiles, amount of agricultural land in the surroundings, location, fire risk, ecological value of the site, and soil nutrients (although no information about this was available).

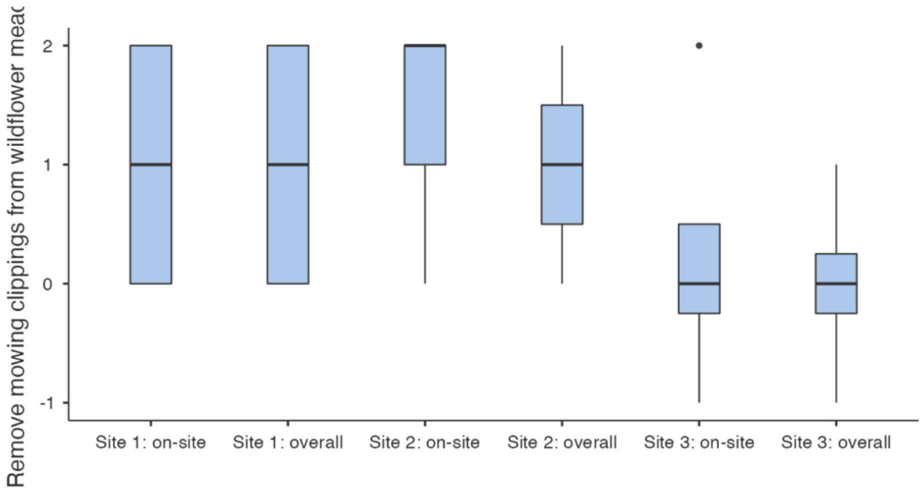
5.1.10 Remove mowing clippings from wildflower meadows

Figure 18 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral and positive evaluations, which is inconsistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Remove mowing clippings from wildflower meadows	Site 1: on-site	4	1.00	2.000	2	0	2
	Site 1: overall	4	1.00	2.000	2	0	2
	Site 2: on-site	3	2	1.000	2	0	2
	Site 2: overall	3	1	1.000	2	0	2
	Site 3: on-site	4	0.00	0.750	3	-1	2
	Site 3: overall	4	0.00	0.500	2	-1	1



- Grassland
- Location
- Surroundings
- Presence of reptile

- Grassland

- Grassland
- Location
- Surroundings
- Vegetation

FIGURE 18: REMOVE MOWING CLIPPINGS FROM WILDFLOWER MEADOWS - IMPACT PER SITE

Like the previous management, experts mentioned that removing mowing clippings prevent nutrient enrichment which favours aggressive dominant plant species. In contrast to semi-natural grassland mowing clippings, clippings from wildflower meadows were mentioned to have a good or negative impact, as if the clippings contain wildflower seeds, they might be beneficial to keep in situ, while if the clippings shade/cover the plant too much, the wildflowers may be outcompeted by more competitive grasses.

Nevertheless, although none of the sites was considered to have a “serious” wildflower meadow, experts mentioned that mowing clippings from wildflower meadows could be used as a method of "green hay" which could be removed from Site 1 and Site 2 and used on other sites, including Site 3, and the wider areas of the PV sites. Moreover, it was mentioned that due to the character of vegetation at Site 3, these clippings could support the distribution of wildflowers seeds. Furthermore, for Site 1 it was suggested again to pile some of the clippings into a heap to make a compost heap, which can be a useful feature for reptiles.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: grassland ecosystem, surroundings, location, vegetation and presence of reptiles.

5.1.11 Block/remove drainage ditches or reduce intensity

Figure 19 presents the descriptive statistics for the experts’ evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Block/remove drainage ditches or reduce intensity	Site 1: on-site	4	1.500	1.25	2	0	2
	Site 1: overall	4	0.500	1.25	2	0	2
	Site 2: on-site	3	2	1.00	2	0	2
	Site 2: overall	3	1	1.00	2	0	2
	Site 3: on-site	4	1.000	2.00	2	0	2
	Site 3: overall	4	1.000	2.00	2	0	2

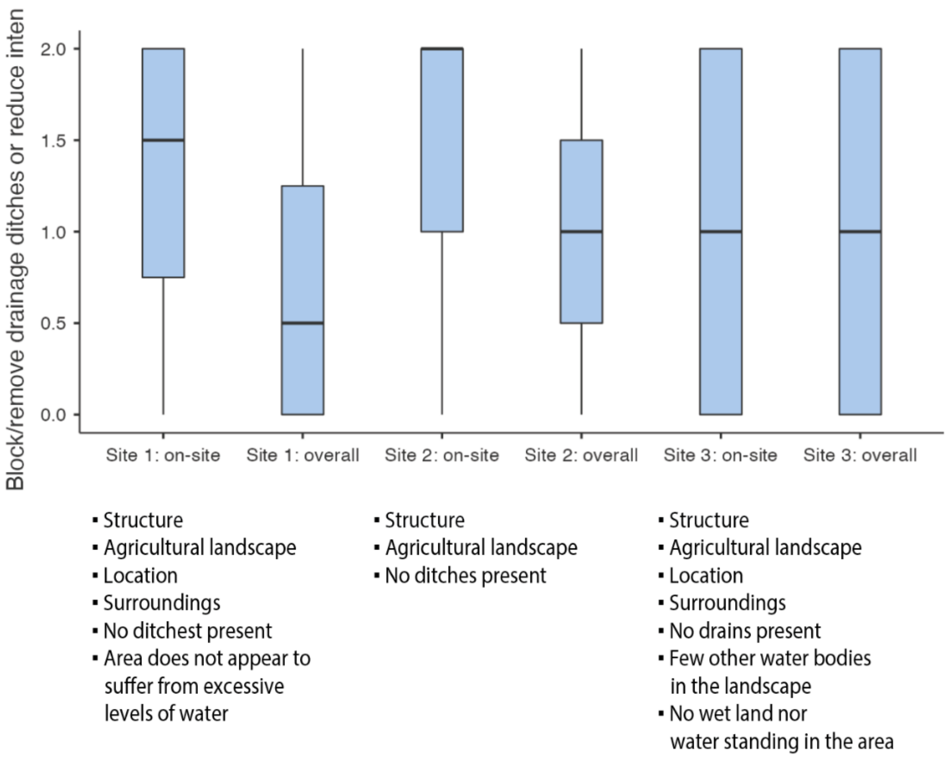


FIGURE 19: BLOCK/ REMOVE DRAINAGE DITCHES OR REDUCE INTENSITY - IMPACT PER SITE

According to the experts, blocking drainage ditches could create standing bodies of water, potentially beneficial for birds and invertebrates (hoverflies, dragonflies etc.). Moreover, it was mentioned that water is very important in an agricultural landscape and that higher water levels at sunny areas of PV sites should be very suitable for different species of Amphibians, therefore, removing drainage would have a positive effect on the water in the broader area and should be conducted to create suitable habitat for Amphibians.

For Site 1 it was mentioned that wetter areas of the site can also add their own biodiversity area, which can be negatively impacted by the presence of ditches and that if there were any ditches, their removal would have a positive effect on the water regime due to evaporation and cooling the surroundings during the hot period.

Meanwhile, for Site 3 was mentioned that as there are few other water bodies in the landscape this MA may be particularly beneficial for this site. In addition, it was pointed out that due to the agricultural nature of the surrounding area, drainage ditches are likely to be present in the vicinity keeping the surroundings relatively dry. Lastly, for this site, due to the local water regime, the removal of any drainage system was considered to have a low effect on biodiversity.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: structure, location in an agricultural landscape, location, surroundings, absence of ditches, absence of excess water/ wet land/ water standing, absence of drains and water bodies in the landscape.

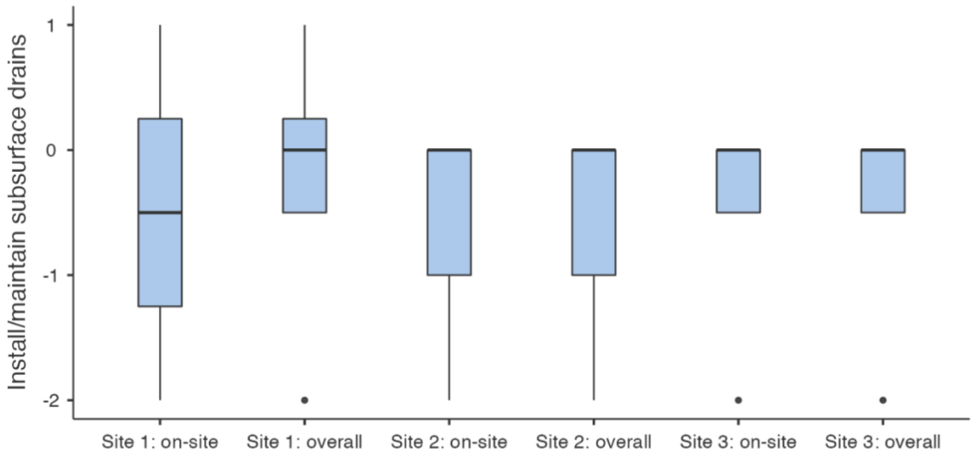
5.1.12 Install/maintain subsurface drains

Figure 20 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral and negative evaluations, which is inconsistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more negative impact on biodiversity within the site than in the surrounding region.

The management action is perceived as less harmful to biodiversity on Site 3 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Install/maintain subsurface drains	Site 1: on-site	4	–0.500	1.500	3	-2	1
	Site 1: overall	4	0.000	0.750	3	-2	1
	Site 2: on-site	3	0	1.000	2	-2	0
	Site 2: overall	3	0	1.000	2	-2	0
	Site 3: on-site	4	0.000	0.500	2	-2	0
	Site 3: overall	4	0.000	0.500	2	-2	0



- Structure
- Agricltural landscape
- Soil conditions
- Landscape conditions
- No wet areas
- Not much surface area without panels

- Structure
- Agricultural landscape
- No excess of water

- Structure
- Agricultural landscape
- No standing water
- Flat area
- Dry area
- Soil aspect
- Annual precipitation of 600m

FIGURE 20: INSTALL/MAINTAIN SUBSURFACE DRAINS - IMPACT PER SITE

For all the sites it was multiple times mention that as they do not appear to have excess water or standing water, this management action for all the sites is unnecessary. Moreover, it was stated that "all forms of drainage systems are unsuitable in today's agricultural landscape". In addition, it was mentioned the impact would depend on if there was standing water and which aspects of biodiversity were targeted for enhancement.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: structure, agricultural landscape, surroundings, soil conditions and aspect, proportion of land covered by panels, flat area, dry area, annual precipitation and absence of wet areas/ excess of water/ standing water.

5.1.13 Install/maintain Sustainable Drainage Systems (SuDS)

Figure 21 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral evaluations, which is inconsistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a similar impact on biodiversity within the site as in the surrounding region.

The management action is perceived as more harmful to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Install/maintain Sustainable Drainage Systems (SuDS)	Site 1: on-site	4	0.00	0.750	3	-2	1
	Site 1: overall	4	0.00	0.750	3	-2	1
	Site 2: on-site	3	0	1.000	2	-2	0
	Site 2: overall	3	0	1.000	2	-2	0
	Site 3: on-site	4	0.00	0.750	3	-2	1
	Site 3: overall	4	0.00	0.750	3	-2	1

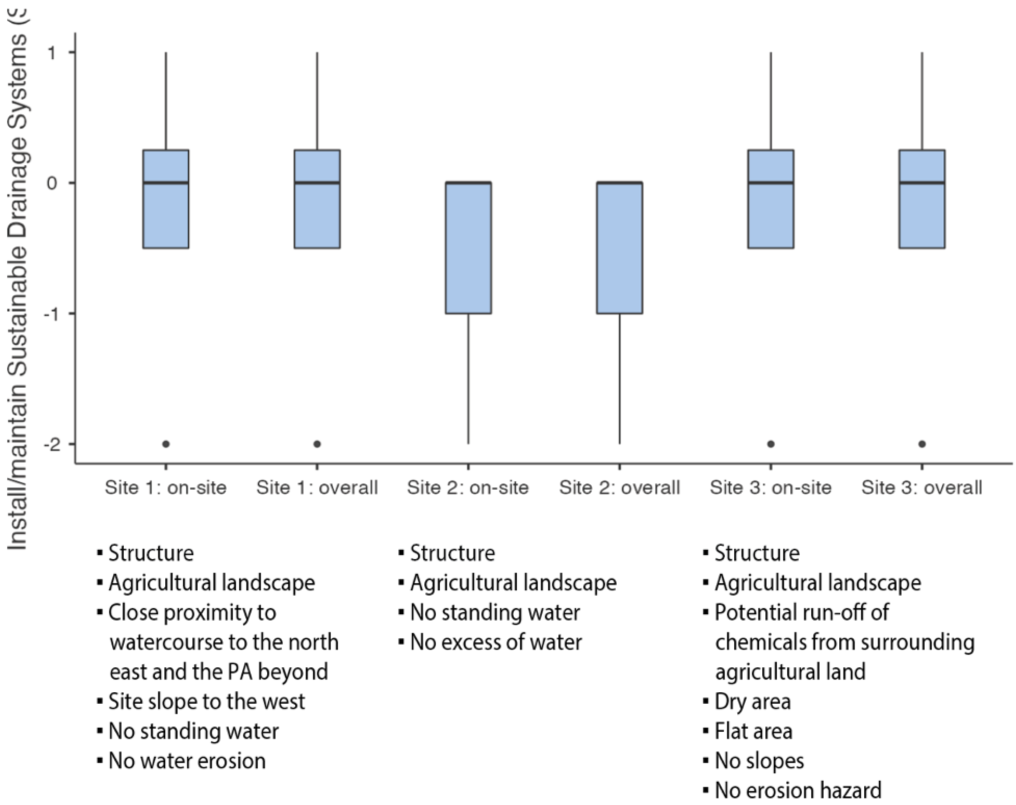


FIGURE 21: INSTALL/MAINTAIN SUSTAINABLE DRAINAGE SYSTEMS (SUDS) - IMPACT PER SITE

Like the previous MA, for all the sites it was multiple times mention that they do not appear to have excess water or standing water. In addition, it was mentioned the impact would depend on if there was standing water and which aspects of biodiversity were targeted for enhancement. Moreover, it was stated again that "all forms of drainage systems are unsuitable in today's agricultural landscape".

In the case of Site 1, it was mentioned that as the site is in close proximity to a watercourse and a PA, it is important that any water that may leave the site does not contaminate and that SUDs can support improving the water quality while also providing habitat for aquatic species, however, as the site slopes to the west, it is unlikely that any water would drain off towards the river system.

For Site 2 it was mentioned that although SUDs can provide biodiversity benefits, standing water does not appear to be a problem, therefore, just creating a series of ponds would be preferable to SUDs.

Regarding Site 3, it was explained that runoff may occur from the crop (maize) field at a slightly higher elevation which may bring nitrogen and phosphorus to the site, therefore, a SUD along the boundary to that arable field may be beneficial to prevent increase N and P loads into the grassland.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: structure, agricultural landscape, proximity of watercourse and PAs, site slopes, potential run-off of chemicals from the surroundings, absence of erosion hazard, flat area, dry area, and absence of wet areas/ excess of water/ standing water.

5.1.14 Connect habitats

Figure 22 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity in the surrounding region than within the site.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Connect habitats	Site 1: on-site	4	1.50	1.000	1	1	2
	Site 1: overall	4	2.00	0.250	1	1	2
	Site 2: on-site	3	2	0.500	1	1	2
	Site 2: overall	3	2	0.000	0	2	2
	Site 3: on-site	4	1.00	2.000	2	0	2
	Site 3: overall	4	1.50	1.000	1	1	2

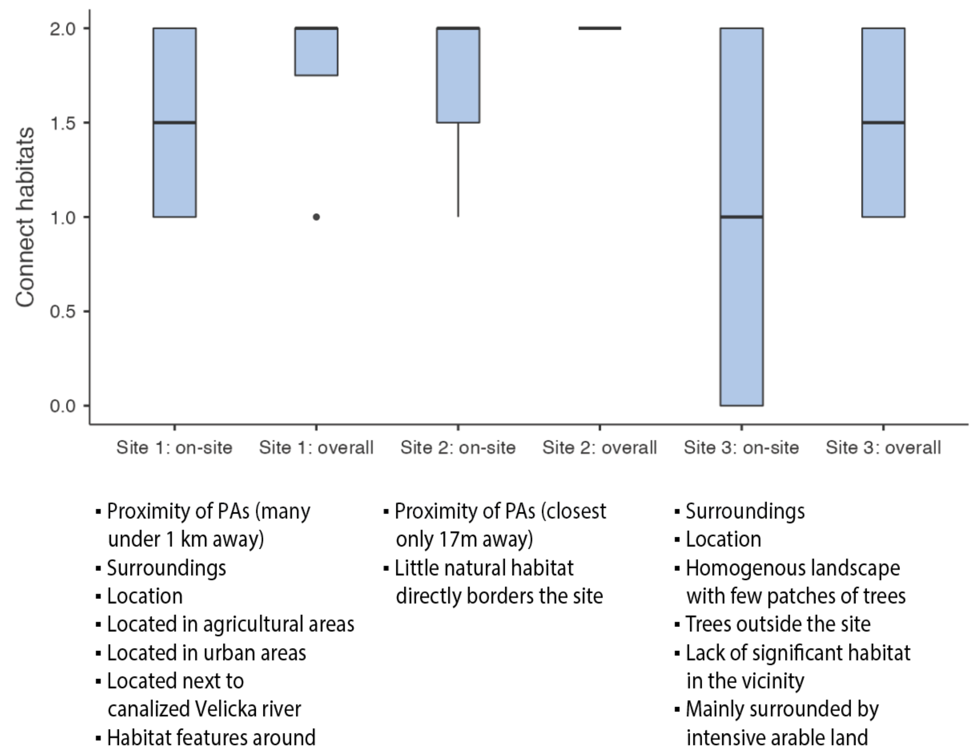


FIGURE 22: CONNECT HABITATS - IMPACT PER SITE

In general, this management action was mentioned to be suitable for improving biodiversity inside and outside the PV sites. The potential of this MA to create hot-spots in the broader area and many new micro-habitats was also pointed out. Additionally, it was specified that connecting habitats could be advantageous for organisms within the site as well as those in the surrounding region that could utilise park resources. Moreover, for Site 1 and Site 2, this MA was considered especially beneficial due to their closeness to protected areas.

Suggestions for Site 1 include:

- Incorporating taller vegetation into the site to connect the river corridor with taller vegetation to the west. This could benefit small mammals, e.g., bats. However, as there is no wildflower grassland in the local area, the site would act more as a stepping stone than a corridor.
- A vegetated corridor along the southeastern boundary. This could support connecting vegetated corridors in the surrounding, but not completely.
- Open the maintained area e.g., towards the Velicka River. This could attract some animals passing by the canalized river to settle inside the PV site.

Suggestions for Site 2 include:

- Hedgerow features with 2m uncut grassland. This can create an important corridor for many different animal species. However, as little natural habitat directly borders the site, this reduces the possibility of directly connecting habitats.

Suggestions and comments for Site 3 include:

- Make the PV park area accessible to the surroundings. This could spread the habitat mosaic for wild animals but makes effective grazing impossible.
- There is a lack of significant habitat in the vicinity of the site with which to connect, except the linear feature in the southeastern boundary which looks of minimal value, and patchy in nature.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: proximity to protected areas, natural habitats bordering the site, homogeneity of the landscape, wooded areas outside the site, location within agricultural areas, location within urban areas, location and surroundings.

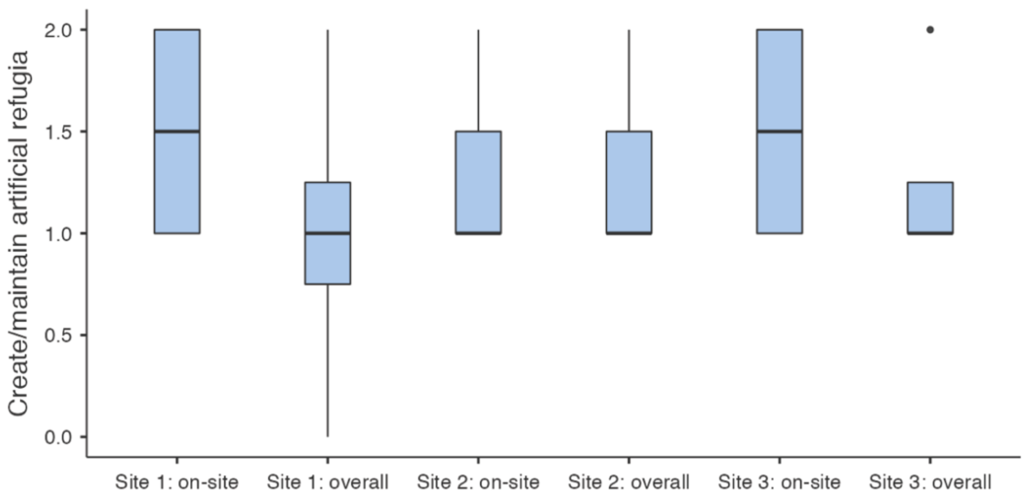
5.1.15 Create/maintain artificial refugia

Figure 23 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 3 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Create/maintain artificial refugia	Site 1: on-site	4	1.50	1.000	1	1	2
	Site 1: overall	4	1.00	0.500	2	0	2
	Site 2: on-site	3	1	0.500	1	1	2
	Site 2: overall	3	1	0.500	1	1	2
	Site 3: on-site	4	1.50	1.000	1	1	2
	Site 3: overall	4	1.00	0.250	1	1	2



- Trees outside the park
- Location
- Surroundings
- Lizards in the vicinity

- Trees outside the park

- Trees outside the park
- Location
- Surroundings
- Lizards seen on the site
- Poor agricultural landscape

FIGURE 23: CREATE/MAINTAIN ARTIFICIAL REFUGIA - IMPACT PER SITE

According to the experts, this management action is beneficial for biodiversity in all the sites. Nonetheless, it was stated that the efficacy of artificial refuges for invertebrates, such as bee nesting boxes, may be mixed, while the efficacy of artificial refuges for other groups, such as bird nest boxes, may be better. Consequently, real refugia through different habitat types e.g., patches of bare ground for bee nesting were suggested to be more beneficial.

Regarding Site 1, this MA was mentioned to have the potential to support some representative species like lizards (stony banks), birds (nesting box), hedgehogs (boxes or heaps of natural material), amphibians (underground refugees) and saproxylic insects (loggers) between others. In addition, log piles were mentioned to possibly provide habitat for stag beetles (one of the species mentioned in the PAs nearby).

Moreover, for Site 2 was explained that this MA would be particularly valuable for any amphibians, reptiles or invertebrates in the locality that require such overwintering habitats. However, it was also mentioned that the need for this artificial refugia may be reduced over time if good quality hedgerow and buffer grass strips are developed.

In the case of Site 3 this management action was considered to possibly provide opportunities for reptiles and insects over winter. Additionally, it was considered that due to the poor agricultural landscape creating bird nest boxes, lizard banks, hedgehog refugia etc., could help raise biodiversity on the site as well as in the surroundings. Lastly, it was advised to make these new structures accessible to target species.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Create/maintain artificial refugia", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Altitude ($p=0.049$, $r2=0.994$), whereby the positive estimate suggests that sites with higher altitudes are associated with a more positive impact of this management action on biodiversity.
- Area of the largest rectangular corridor ($p=0.012$, $r2=1$), whereby the negative estimate suggests that sites with larger rectangular areas without panels are associated with a less positive impact of this management action on biodiversity.

Although these 2 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: species in protected areas nearby, trees outside the park, location, surroundings, presence of lizards inside the site and/ or in the vicinity, and poor agricultural landscape.

5.1.16 Create/maintain artificial wetlands or wet features

Figure 24 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a similar positive impact on biodiversity within the site and in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Create/maintain artificial wetlands or wet features	Site 1: on-site	4	1.50	1.250	2	0	2
	Site 1: overall	4	1.50	1.250	2	0	2
	Site 2: on-site	3	2	1.000	2	0	2
	Site 2: overall	3	2	1.000	2	0	2
	Site 3: on-site	4	1.00	0.250	1	1	2
	Site 3: overall	4	1.50	1.250	2	0	2

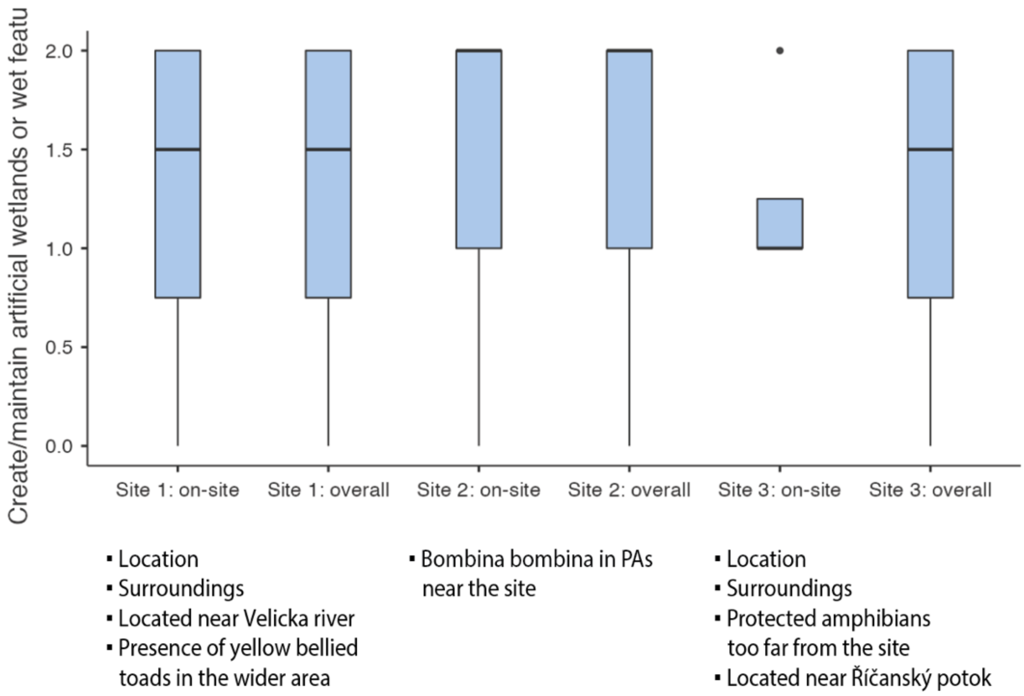


FIGURE 24: CREATE/MAINTAIN ARTIFICIAL WETLANDS OR WET FEATURES - IMPACT PER SITE

For all the sites this MA was considered beneficial for the experts. Nonetheless, it was mentioned that the benefits of this action would depend on the groups targeted for conservation and the existing habitat types within the park. In addition, for Site 1 and Site 3, experts expressed mixed opinions on whether there is enough space for wet features inside the site or not.

For Site 1 was stated that a series of small ponds support a significant number of aquatic species and that due to the presence of *yellow bellied toads* in the wider area of this site, the installation of concrete ponds that are favoured by such species requiring pioneer habitats could be beneficial. Moreover, it was mentioned that the open grassland in the southern corner of the site could provide an opportunity to create one or more small ponds. Additionally, experts suggested considering rainfall when deciding whether to incorporate ponds, as having to artificially fill them in the spring could affect their feasibility.

For Site 2, it was mentioned that wetland features/series of small ponds could provide habitat for the species Bombina *bombina* (a notable species in the protected areas near the site), other amphibians and a large number of invertebrates, e.g., odonata species. Furthermore, wet features were suggested in the site along the northeast boundary of the site where is a strip of land without panels as this could be a potential location for a series of small ponds that do not interfere with vehicle movements related to the site and, in the land in the southern corner, reviewing that is undisturbed.

Lastly, for Site 3 it was mentioned that creating some small pools at the south-east border using water from Říčanský potok would attract wild animals as well as some rarer plant species to settle in the site. Nevertheless, it was also mentioned that designations supporting protected amphibians are too far away for wet features in the site to be beneficial and that if sheep grazing continues these features may get poached/degraded.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: location, surroundings, species in PAs nearby, species in the locality, waterbodies nearby, and distance from PAs that protect amphibians.

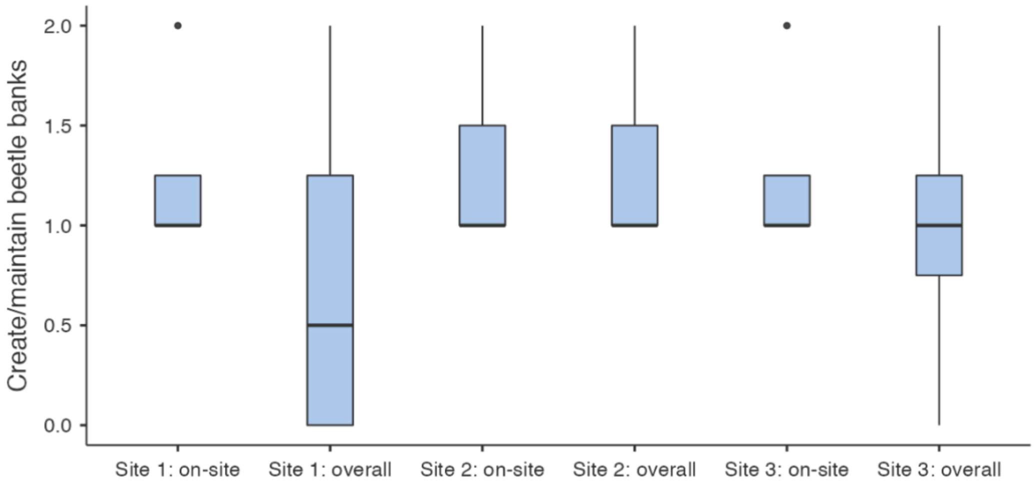
5.1.17 Create/maintain beetle banks

Figure 25 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral and positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Create/maintain beetle banks	Site 1: on-site	4	1.000	0.250	1	1	2
	Site 1: overall	4	0.500	1.250	2	0	2
	Site 2: on-site	3	1	0.500	1	1	2
	Site 2: overall	3	1	0.500	1	1	2
	Site 3: on-site	4	1.000	0.250	1	1	2
	Site 3: overall	4	1.000	0.500	2	0	2



- Location
- Surroundings
- Woodland area adjacent
- Climate region
- Site inside PA Bile Karpaty

- Large strip of unused land

- Location
- Surroundings
- Arable landscape
- Intensive agriculture in the wider area
- Not enough space

FIGURE 25: CREATE/MAINTAIN BEETLE BANKS - IMPACT PER SITE

This management action in general was considered beneficial for biodiversity by the experts, and it was mentioned that if these beetle banks are made of logs they could also be utilised by small mammals.

Regarding Site 1, it was mentioned that due to the climate region and the protected area where is located, there is a high potential for rare insect species occurrence and this feature could benefit these species. Additionally, it was stated that beetle banks should be left with long vegetation over the winter to allow overwintering habitats for invertebrates and that in this site it could be incorporated along one of the boundaries but would need to be developed simultaneously with a feature that would produce waste soils in order to build up such a bank, e.g., the incorporation of a SUDs or ponds. However, the impact on the wider area was mentioned to be possibly insignificant as the woodland area adjacent would offer far more habitat opportunities.

Meanwhile, a suggestion for Site 2 was to explore this MA only if a wildflower meadow covering the majority of the site is not a viable option and a potential location may be along the northeast boundary, where there is a large strip of unused land.

For Site 3 was stated that a beetle bank is a good feature within an arable landscape, providing overwintering habitat for insects, that utilise the agriculture fields in the summer months. Moreover, it was considered that due to the intensive agriculture in the wider area, there are no beetle banks in the surroundings, therefore creating such a feature could raise the number of insect species and their abundance. However, it was also mentioned that this MA may not be viable due to the lack of enough space and the grazing regime, as beetle banks are meant to be left with long vegetation through the winter months.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: location, surroundings, adjacent woodland areas, location inside PA, climate region, areas without panels, and arable landscape.

5.1.18 Create/maintain buffer zones/field margins/set-aside

Figure 26 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Create/maintain buffer zones/field margins/set-aside	Site 1: on-site	4	1.50	1.25	2	0	2
	Site 1: overall	4	1.00	2.00	2	0	2
	Site 2: on-site	3	2	1.00	2	0	2
	Site 2: overall	3	2	1.00	2	0	2
	Site 3: on-site	4	1.50	1.00	1	1	2
	Site 3: overall	4	1.50	1.25	2	0	2

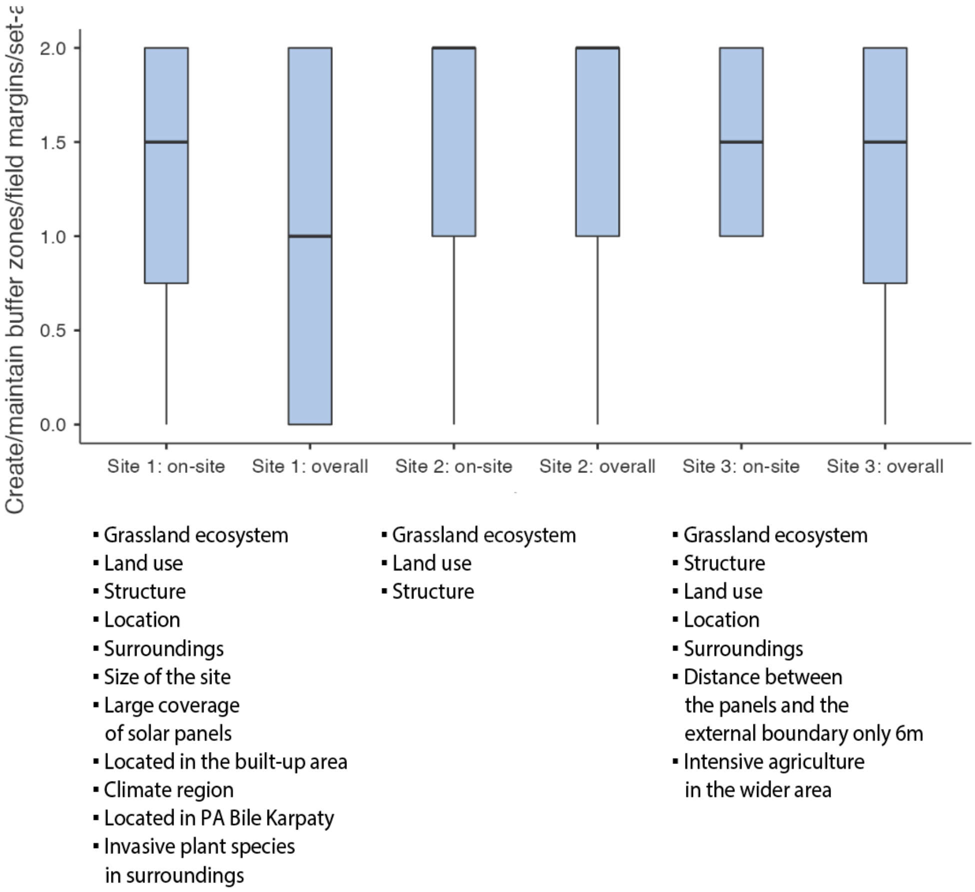


FIGURE 26: CREATE/MAINTAIN BUFFER ZONES/FIELD MARGINS/SET-ASIDE - IMPACT PER SITE

In general, experts agreed that creating habitat or managing habitat differently in the outskirts of the site would be beneficial for a wide range of groups (invertebrates, birds, small mammals).

For Site 1 was stated that although the site is located within the built-up area, due to the climate region and its location inside the PA Bile Karpaty, there is a high potential of rare insect species occurrence which could benefit from this feature. However, it was considered that there is an environmental risk of invasive species occurrence. In addition, it was mentioned that due to the size of the site and the large coverage of the panels, creating/ managing just one habitat would be more efficient and that wildflower grassland would provide more benefits than buffer zones.

Similarly, for Site 2 was mentioned that other habitats would be preferred over this, but if hedgerows are incorporated and the remaining of the site is kept well managed a 2m buffer of uncut grass should be kept.

The positive potential of this MA due to the intensive agriculture in the wider area was mentioned again for Site 3. Additionally, for this site was mentioned that this could work in the site given that the distance between panels and the external boundary is only 6m in places. It was also stated that these areas should be margins of at least 2 and up to 6m, they should be cut every 3 years and if grazing is the continued method of management, then any field margins would need to be fenced off.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Create/maintain buffer zones/field margins/set-aside", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Altitude (p=0.049, r2=0.994), whereby the negative estimate suggests that sites with higher altitudes are associated with a less positive impact of this management action on biodiversity.
- Area of the largest rectangular corridor (p=0.012, r2=1), whereby the positive estimate suggests that sites with larger rectangular areas without panels are associated with a more positive impact of this management action on biodiversity.

Although these 2 site characteristics were not mentioned directly by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the most relevant site characteristics to evaluate the impact of this management action by the experts were: grassland ecosystem, land use, structure, location, surroundings, size of the site, proportion of land covered with panels, distance between panels and fence, location in PA, location in built-up areas, location in agricultural areas, invasive plant species nearby and climate region.

5.1.19 Install/maintain bat boxes

Figure 27 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity in the surrounding region than within the site (for Site 3).

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Install/maintain bat boxes	Site 1: on-site	4	1.00	2.00	2	0	2
	Site 1: overall	4	1.00	2.00	2	0	2
	Site 2: on-site	3	2	1.00	2	0	2
	Site 2: overall	3	2	1.00	2	0	2
	Site 3: on-site	4	1.00	2.00	2	0	2
	Site 3: overall	4	1.50	1.25	2	0	2

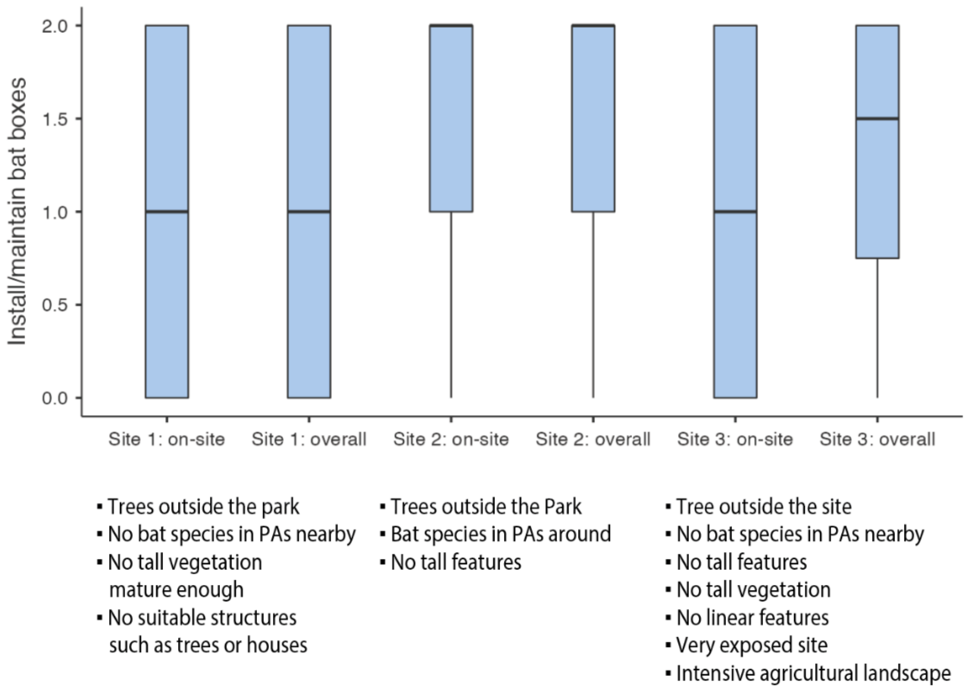


FIGURE 27: INSTALL/MAINTAIN BAT BOXES - IMPACT PER SITE

In general, experts agree that this MA could have a positive impact on biodiversity and it was explained that this could help to provide a roost for bats in the surroundings of the sites. Although some experts believed that bat boxes could be installed on all sites, others claimed that the sites lack appropriate tall features for these, and therefore that this MA is not suitable.

For Site 1 and Site 3 was mentioned that although there are no protected bat species in nearby PAs, the bat boxes could benefit widespread species. Meanwhile, for Site 2 the MA was considered especially beneficial because of bat species of interest recorded in nearby protected areas.

Moreover, for Site 1 was explained that the taller vegetation of the river corridor offers better opportunities than on-site, although the offsite installation of bat boxes in this area could be beneficial. Meanwhile, for Site 2 was mentioned that although the nearby woodland is likely to provide preferable roosting habitats if the hedgerows trees are included, once these mature, bat boxes could be used. Lastly, for Site 3 was mentioned that the agricultural landscape is usually poor in habitat offers, especially for bats, therefore the trees at the southeast border of the site could be suitable.

A regression analysis attempted to predict the median “on-site” evaluations for this management action, “Install/maintain bat boxes”, using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts’ evaluations of the biodiversity impact:

- Altitude ($p=0.049$, $r2=0.994$), whereby the negative estimate suggests that sites with higher altitudes are associated with a less positive impact of this management action on biodiversity.
- Area of the largest rectangular corridor ($p=0.012$, $r2=1$), whereby the positive estimate suggests that sites with larger rectangular areas without panels are associated with a more positive impact of this management action on biodiversity.

Although these 2 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: the presence of suitable features (e.g., older and taller trees or houses) inside the site, the scarcity of bat habitats in the surroundings and the species of interest in nearby protected areas.

5.1.20 Install/maintain beehives

Figure 28 presents the descriptive statistics for the experts’ evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral and negative evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more negative impact on biodiversity in the surrounding region than within the site (for Site 2).

The management action is perceived as less harmful to biodiversity on Site 3 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Install/maintain beehives	Site 1: on-site	4	–0.500	1.75	4	-2	2
	Site 1: overall	4	–0.500	1.75	4	-2	2
	Site 2: on-site	3	-1	1.50	3	-1	2
	Site 2: overall	3	-1	2.00	4	-2	2
	Site 3: on-site	4	0.000	2.25	3	-1	2
	Site 3: overall	4	0.000	2.25	3	-1	2

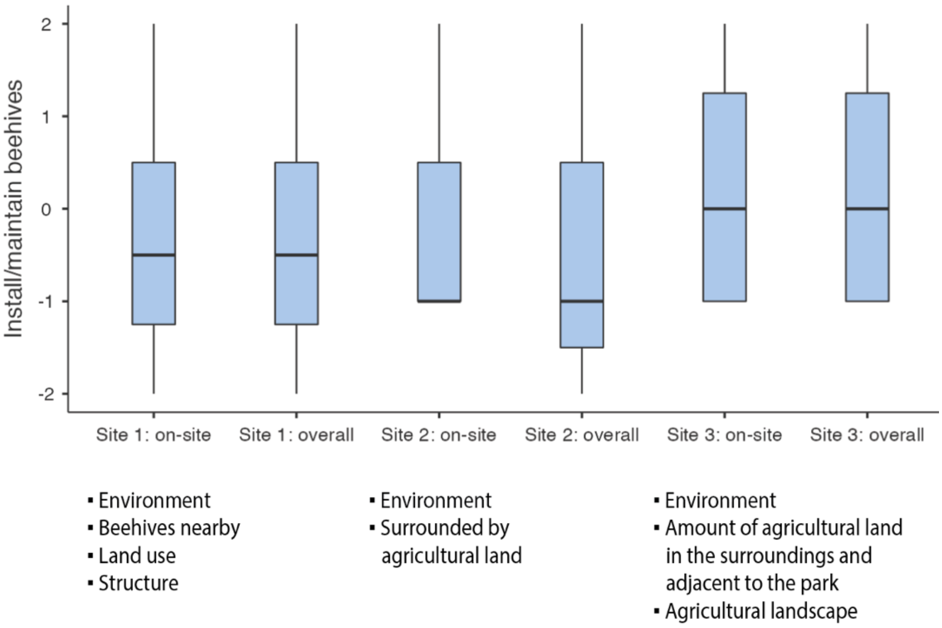


FIGURE 28: INSTALL/MAINTAIN BEEHIVES - IMPACT PER SITE

Half of the experts considered that this management action could have a negative impact on biodiversity across all three sites, stating that there is evidence that managed pollinators like honeybees have negative impacts on wild species (competition for resources, disease etc.) at certain densities. On the contrary, the only strong positive evaluation across all the sites considered all of the habitat-related MAs for all the sites in this study very suitable for improving biodiversity on PV sites and creating hot spots in the broader area.

For Site 1, experts stated that as beehives are already nearby, it is not recommended to add to these, as adding more managed bees to this system might have a negative impact on the wild pollinator population. Meanwhile, for Site 2 and Site 3, it was considered that this MA could be beneficial to crop pollination when surrounded by agricultural land. In addition, it was mentioned Site 3 evaluation that beekeeping has always positive effect on horticulture and biodiversity and even more in the middle of the agricultural landscape.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: the presence of beehives in the surrounding areas, environment, land use, structure and agricultural surroundings.

5.1.21 Install/maintain bird boxes

Figure 29 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having the same impact on biodiversity within the site as in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Install/maintain bird boxes	Site 1: on-site	4	1.00	2.00	2	0	2
	Site 1: overall	4	1.00	2.00	2	0	2
	Site 2: on-site	3	2	1.00	2	0	2
	Site 2: overall	3	2	1.00	2	0	2
	Site 3: on-site	4	1.50	1.25	2	0	2
	Site 3: overall	4	1.50	1.25	2	0	2

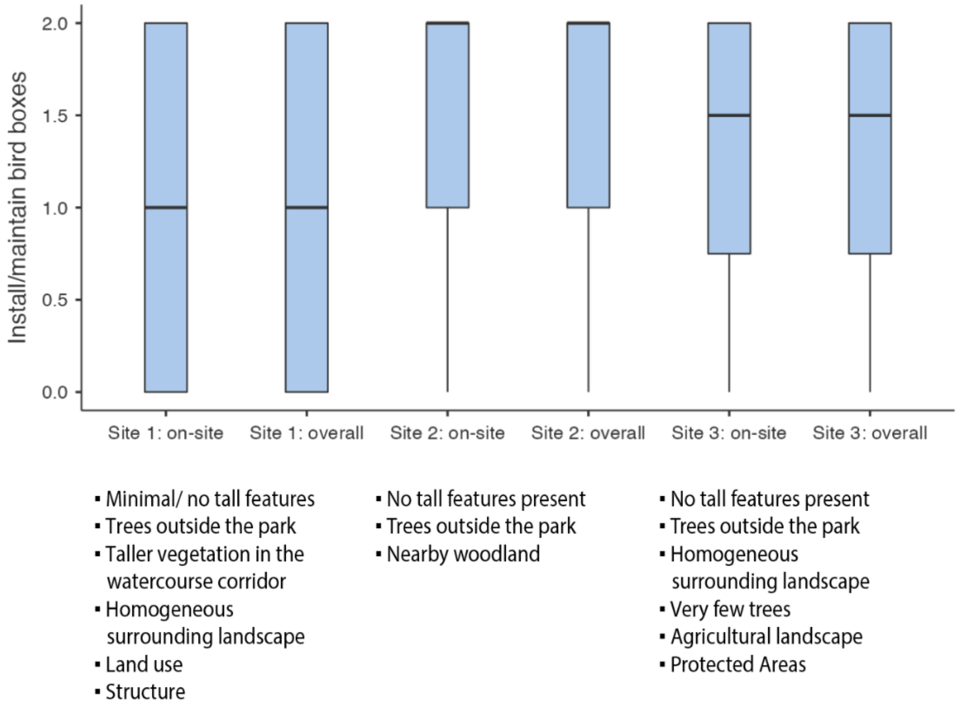


FIGURE 29: INSTALL/MAINTAIN BIRD BOXES - IMPACT PER SITE

In general, experts agreed that this management action could be beneficial to biodiversity. It was stated that installing and maintaining bird boxes might provide nesting sites for certain species and that the type of bird box could be targeted to specific species of interest. Although some experts believed that bird boxes could be installed on all sites, others claimed that the sites lack appropriate tall features for these, and therefore that this MA is not suitable. Moreover, it was explained that old cavernal trees are generally preferred for bird nesting.

For Site 1 and Site 3, it was mentioned that this MA could be important due to the surrounding homogeneous landscape and the scarcity of other nesting sites. Moreover, for Site 1 was explained that the taller vegetation of the watercourse corridor offers better habitat for nesting birds and that, given the presence of mice in the area and the agricultural setting, a barn owl, which could be installed on a free-standing pole, could be a suitable feature. Meanwhile, for Site 2 was mentioned that although the nearby woodland is likely to provide preferable roosting habitats if the hedgerows trees are included, once these mature, bird boxes could be used. Lastly, for Site 3 was mentioned that as there are few suitable trees in the agricultural landscape, it is possible to install bird boxes in the younger trees (e.g., at the southeast border of the site or along the watercourse).

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: the presence of suitable features (e.g., older and taller trees or houses) inside the site, homogeneity of the surroundings, land use, structure, protected areas nearby, agricultural landscape, wooded vegetation outside the site and the scarcity of more suitable nesting sites in the surroundings.

5.1.22 Plant/maintain wildflowers/nectar seed meadows

Figure 30 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more positive to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Plant/maintain wildflowers/nectar seed meadows	Site 1: on-site	4	2.00	0.000	0	2	2
	Site 1: overall	4	1.50	1.000	1	1	2
	Site 2: on-site	3	2	0.000	0	2	2
	Site 2: overall	3	2	0.000	0	2	2
	Site 3: on-site	4	2.00	0.000	0	2	2
	Site 3: overall	4	2.00	0.250	1	1	2

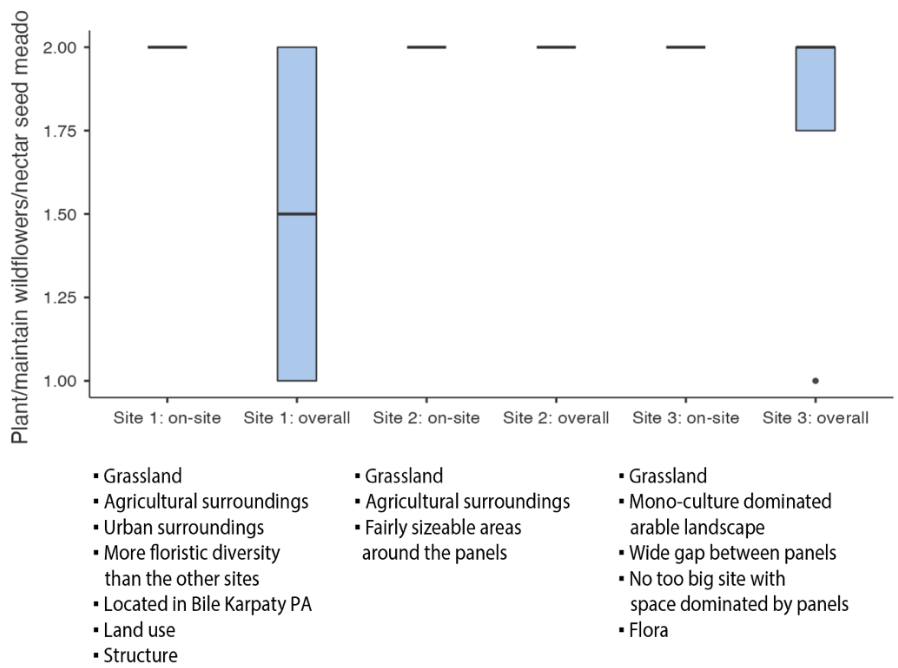


FIGURE 30: PLANT/ MAINTAIN WILDFLOWERS/ NECTAR MEADOWS - IMPACT PER SITE

In general, all experts agreed that this MA could have a positive impact on biodiversity within and beyond the sites. It was explained that encouraging flowers across the sites would benefit a variety of invertebrates and, as a result, any organisms that feed on them, and that certain flowering plant species that produce seeds may also benefit birds.

For Site 1, it was recognised that due to the agricultural and urban nature of the surrounding area, the development of a wildflower meadow would provide significant opportunities for pollinators, a variety of other invertebrates, small mammals, and herpetofauna. It was also explained that despite the fact that the site appears to have a greater floristic diversity than the other PV sites, it would be optimal to build upon and improve this. The suggestions for this site include: (1) establishing flowers in the margin areas and between sections of panels; (2) promoting natural regeneration along fencelines; and (3) utilising a mountains meadows grass mixture due to the location of the PA.

For Site 2, it was stated that the large area of grassland around and between the panels has great potential to be enhanced as wildflower meadows with substantial wildlife value, supporting pollinators and providing pollination services to the neighbouring agricultural land.

Lastly, this MA for Site 3 was considered to have the potential to substantially increase the site's ecological value, particularly for insects and pollinators. It was also mentioned that this is a low-maintenance habitat that is compatible with solar panels and works well with grazing management (though this would need to be reduced in time and intensity). Furthermore, recommendations include growing wildflower meadows to enrich the margins and between the panels, bringing a valuable resource, especially to insects, in what is a very monoculture-dominated arable landscape.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: flora, floristic diversity, urban surroundings, agricultural surroundings, location in PA, size of areas without panels, size of the site, land use, and structure.

5.1.23 Reduce pollution and green waste inputs into ditches

Figure 31 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is inconsistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity in the surrounding region than within the site (for Site 1).

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Reduce pollution and green waste inputs into ditches	Site 1: on-site	4	1.00	2.000	2	0	2
	Site 1: overall	4	1.50	1.250	2	0	2
	Site 2: on-site	3	2	0.500	1	1	2
	Site 2: overall	3	2	0.500	1	1	2
	Site 3: on-site	4	1.50	1.250	2	0	2
	Site 3: overall	4	1.50	1.250	2	0	2

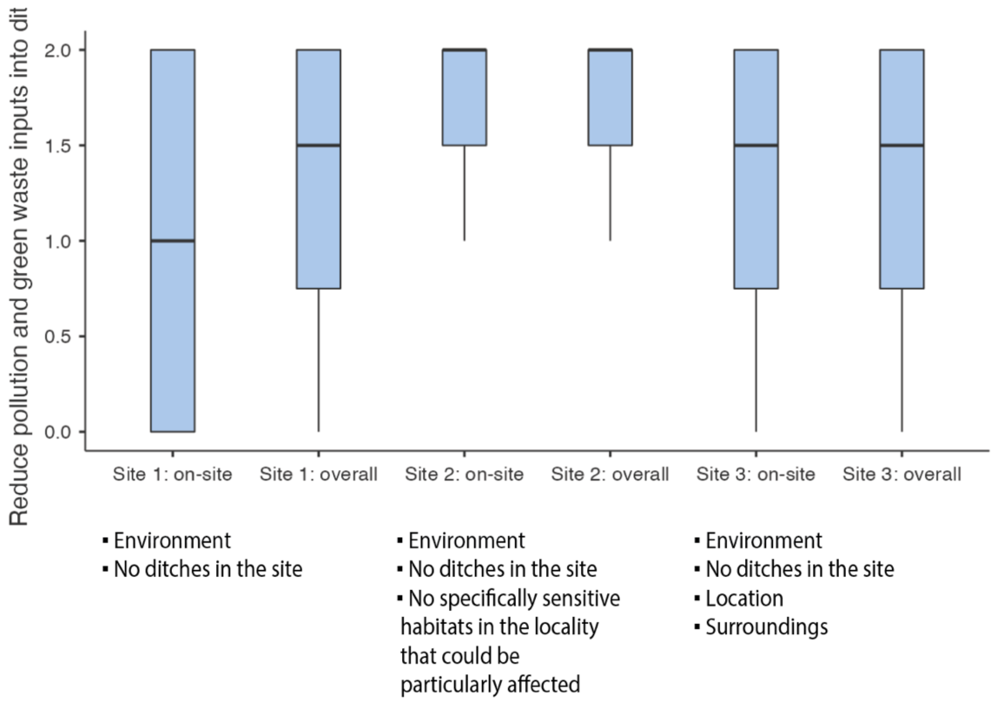


FIGURE 31: REDUCE POLLUTION AND GREEN WASTE INPUTS INTO DITCHES – IMPACT PER SITE

According to the experts, this MA could have a positive impact on biodiversity as it prevents chemicals from entering the local environment. However, the possibility of this MA to have both positive and negative impacts was also mentioned. It was explained that in some cases heaps of green waste could provide an extra environmental niche for birds as well as reptiles and their preys.

Although experts considered that none of the sites presented ditches the experts expressed their opinion in case this would be different. For Site 1, it was stated that this MA would reduce the impact on external habitats. For Site 2, it was mentioned that although the best practise is to not allow pollution and green waste into the wider environment, no especially sensitive habitats in the area would be affected. Lastly, for Site 3, it was mentioned that no pollution should enter ditches because it poses an ecological threat and has the potential to spread offsite through water flow, and that green waste can decompose and increase the nutrient levels of water in ditches negatively impacting both on-site and off-site biodiversity.

Overall, the relevant site characteristic to evaluate the impact of this management action by the experts were: environment, absence of ditches, location, surroundings and the habitats in the site as well as in the surrounding areas.

5.1.24 Reduce/cease pesticide and fertilizer use if previously used

Figure 32 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 1 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Reduce/cease pesticide and fertilizer use if previously used	Site 1: on-site	4	2.00	0.250	1	1	2
	Site 1: overall	4	1.00	0.250	1	1	2
	Site 2: on-site	3	2	1.000	2	0	2
	Site 2: overall	3	1	1.000	2	0	2
	Site 3: on-site	4	1.50	1.000	1	1	2
	Site 3: overall	4	1.00	0.500	2	0	2

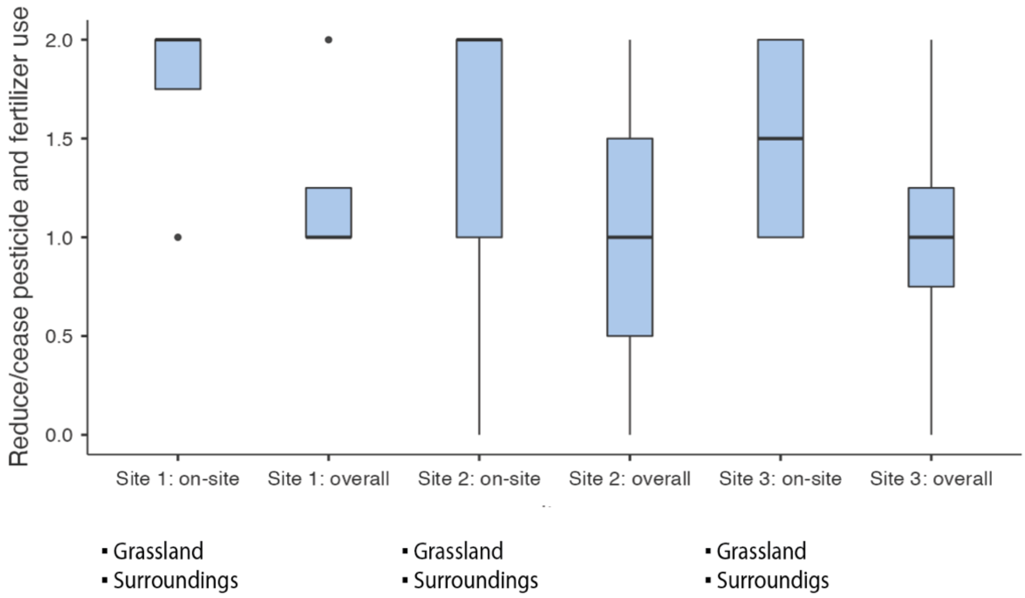


FIGURE 32: REDUCE/ CEASE PESTICIDE AND FERTILIZER USE IF PREVIOUSLY USED – IMPACT PER SITE

Although no chemicals have been used in the sites since 2021 and experts suggested ensuring that these are not used in the future, experts shared their opinion about this management action.

According to the experts, in general, this MA has a positive impact on biodiversity as (1) reducing pesticide use will benefit invertebrates and provide a refuge for those in the wider landscape if they are used in the surroundings e.g., on crops; (2) reducing fertiliser use will input fewer nutrients into the soil and make wildflowers more competitive against grasses; (3) halting herbicide should allow vegetation to grow and floral diversity to increase.

Experts explained that chemicals and their residuals remain in both water and soil for a very long time negatively affecting many species, especially insects and aquatic animals. In addition, it was suggested that grazing animals should eliminate the need for herbicides, and if undesirable plants remain, they should be trimmed and not treated with chemicals. On the other hand, it was mentioned that although pesticide use is responsible for biodiversity decline in the wild in general, there could be also a positive effect in the case of alien species eradication.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Reduce/cease pesticide and fertilizer use if previously use", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Distance from a PA that protects amphibians ($p=0.016$, $r2=0.999$), whereby the negative estimate suggests that sites with longer distances from a PA that protects amphibians are associated with a less positive impact of this management action on biodiversity.
- Distance from a PA that protects invertebrates ($p=0.016$, $r2=0.999$), whereby the negative estimate suggests that sites with longer distances from a PA that protects invertebrates are associated with a less positive impact of this management action on biodiversity.
- Distance from the closest N2K PA ($p=0.030$, $r2=0.998$), whereby the negative estimate suggests that sites with longer distances from a N2K PA are associated with less positive impact of this management action on biodiversity.
- Distance from the closest PA ($p=0.002$, $r2=1$), whereby the negative estimate suggests that sites with longer distances from a PA that protects amphibians are associated with a less positive impact of this management action on biodiversity.

Although these 4 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were the environment of the sites and their surroundings.

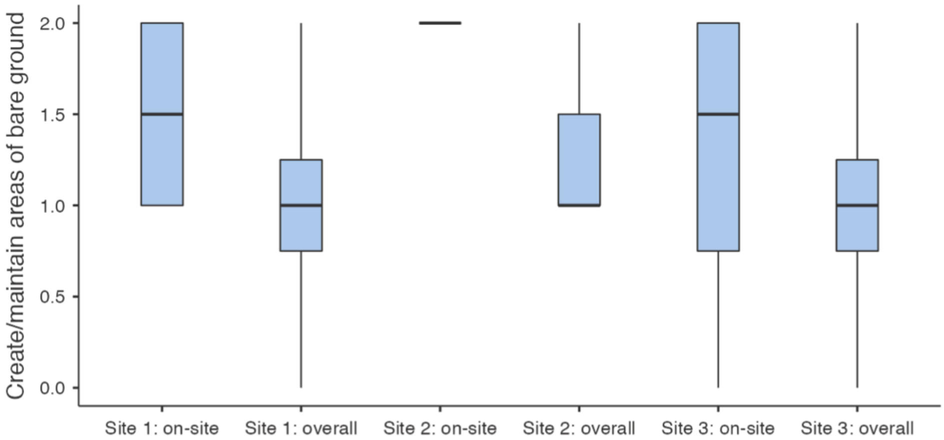
5.1.25 Create/maintain areas of bare ground

Figure 33 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Create/maintain areas of bare ground	Site 1: on-site	4	1.50	1.000	1	1	2
	Site 1: overall	4	1.00	0.500	2	0	2
	Site 2: on-site	3	2	0.000	0	2	2
	Site 2: overall	3	1	0.500	1	1	2
	Site 3: on-site	4	1.50	1.250	2	0	2
	Site 3: overall	4	1.00	0.500	2	0	2



Site 1:
- Environment

Site 2:
- Environment
- Existing patches of bare ground

Site 3:
- Environment
- Existing patches of bare ground
- Lizards seen in the area
- Flora

FIGURE 33: CREATE/ MAINTAIN AREAS OF BARE GROUND - IMPACT PER SITE

Experts generally agreed that this MA could have a positive impact on biodiversity both inside and outside the sites as bare ground provides important habitat for ground burrowing insect species, such as mining bees, and could support pioneer plant species (if realised mechanically not by use of chemicals) as well as competitively weak plant species and Arthorpods that are closely related to these. It was also stated that areas of bare ground may happen anyway if grazing animals are being used in the management. Nonetheless, it was explained that this MA could also provide some open habitat for alien plant species from the surroundings (if there are any).

Regarding Site 3, experts mentioned that this MA would raise habitat mosaic on the site and also benefit lizards seen in the area to bask and warm up.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Create/ maintain areas of bare ground", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Altitude (p=0.049, r2=0.994), whereby the negative estimate suggests that sites with higher altitudes are associated with a less positive impact of this management action on biodiversity.
- Area of the largest rectangular corridor (p=0.012, r2=1), whereby the positive estimate suggests that sites with larger rectangular areas without panels are associated with a more positive impact of this management action on biodiversity.

Although these 2 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: environment, flora, presence of patches of bare ground, presence of lizards and surroundings.

5.1.26 Cut sod

Figure 34 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having the same impact on biodiversity within the site as in the surrounding region.

The management action is perceived as the same positive to biodiversity on all the sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Cut sod	Site 1: on-site	2	0.500	0.500	1	0	1
	Site 1: overall	2	0.500	0.500	1	0	1
	Site 2: on-site	2	0.500	0.500	1	0	1
	Site 2: overall	2	0.500	0.500	1	0	1
	Site 3: on-site	2	0.500	0.500	1	0	1
	Site 3: overall	2	0.500	0.500	1	0	1

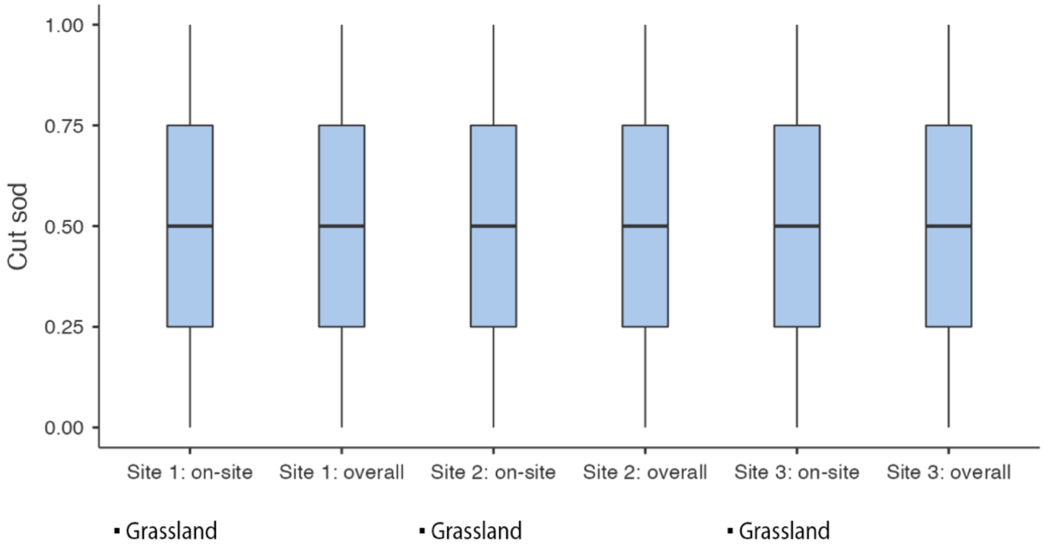


FIGURE 34: CUT SOD - IMPACT PER SITE

While half of the experts did not evaluate this management action, the other half evaluated this identically across all the sites. According to the experts, the cutting of sod has the potential to support a seed bank and by enhancing biodiversity at PV sites, it has the potential to disperse these positive effects over a larger area. However, it was mentioned that the impact would depend on the existing vegetation and it was suggested to try the effect of this form of care on some smaller places and monitor the real effect.

Overall, the relevant site characteristic to evaluate the impact of this management action by the experts was the existing vegetation on the site.

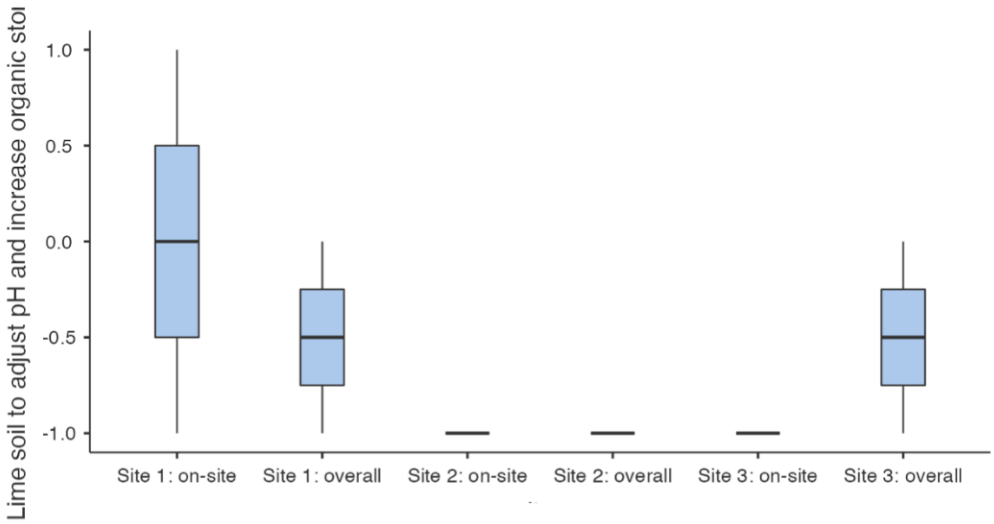
5.1.27 Lime soil to adjust pH and increase organic storage

Figure 35 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral and negative evaluations, which is inconsistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more negative impact on biodiversity within the site than in the surrounding region.

The management action is perceived as less harmful to biodiversity on Site 1 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Lime soil to adjust pH and increase organic storage	Site 1: on-site	2	0.000	1.000	2	-1	1
	Site 1: overall	2	−0.500	0.500	1	-1	0
	Site 2: on-site	1	-1	0.000	0	-1	-1
	Site 2: overall	1	-1	0.000	0	-1	-1
	Site 3: on-site	2	−1.000	0.000	0	-1	-1
	Site 3: overall	2	−0.500	0.500	1	-1	0



- Soil pH

- Soil pH
- Environment

FIGURE 35: LIME SOIL TO ADJUST PH AND INCREASE ORGANIC STORAGE - IMPACT PER SITE

Although few evaluations were received for this MA, it was mentioned for all the sites that the increase of organic storage would have a negative effect as higher eutrophication would increase overgrowth and disperse of both expansive and invasive plant species. Moreover, for Site 1 was mentioned that as the soil pH seems to be optimal, there is no reason for liming and for Site 3 that as the soil pH seems to be almost optimal, liming would have no positive effect on the soil quality.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were soil pH and environment.

5.1.28 Remove topsoil

Figure 36 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region for Site 1 while more positive impact on biodiversity in the surrounding region than within the site for Site 3.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Remove topsoil	Site 1: on-site	3	1	0.000	0	1	1
	Site 1: overall	3	0	0.500	1	0	1
	Site 2: on-site	1	1	0.000	0	1	1
	Site 2: overall	1	1	0.000	0	1	1
	Site 3: on-site	2	0.000	1.000	2	-1	1
	Site 3: overall	2	0.500	0.500	1	0	1

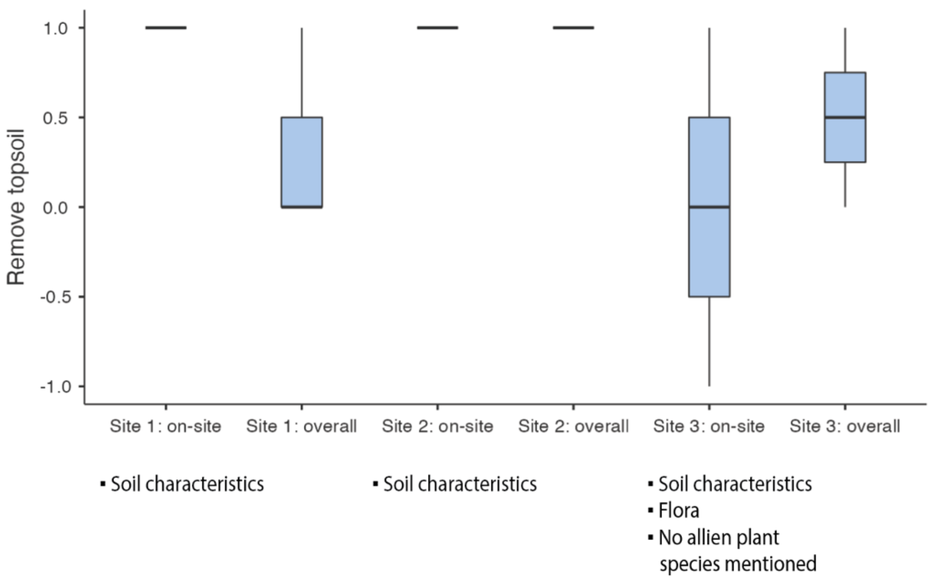


FIGURE 36: REMOVE TOP SOIL - IMPACT PER SITE

It was mentioned for all sites that removing topsoil could be beneficial if the intention is to restore or create a new habitat type in the sites, which would ultimately enhance bio-diversity; however, removing top soil could cause a lot of disturbance, which could have a negative impact if it was of good quality.

For Site 1 was mentioned that this management action supports pioneer plant species and rare stenoeic species. Moreover, it was explained that if the site was previously used for agricultural purposes, the top soil may have been artificially enriched, which is incompatible with high bio-diverse grassland. It was also suggested that in such case the topsoil could be used to create beetle banks or boundary features. Nonetheless, this MA was considered to be a costly process which is only possible in areas not occupied by the panels, and should be seen as last option.

Meanwhile for Site 3 was mentioned that as no allien plant species were mentioned on the site there is probably no relevant reason to remove the topsoil.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Remove topsoil", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Distance from a PA that protects amphibians ($p=0.016$, $r2=0.999$), whereby the negative estimate suggests that sites with longer distances from a PA that protects amphibians are associated with a less positive impact of this management action on biodiversity.
- Distance from a PA that protects invertebrates ($p=0.016$, $r2=0.999$), whereby the negative estimate suggests that sites with longer distances from a PA that protects invertebrates are associated with a less positive impact of this management action on biodiversity.
- Distance from the closest N2K PA ($p=0.030$, $r2=0.998$), whereby the negative estimate suggests that sites with longer distances from a N2K PA are associated with a less positive impact of this management action on biodiversity.
- Distance from the closest PA ($p=0.002$, $r2=1$), whereby the negative estimate suggests that sites with longer distances from a PA that protects amphibians are associated with a less positive impact of this management action on biodiversity.

Although these 4 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: the soil characteristics, soil quality, previous land use, and presence of alien plant species.

5.1.29 Replace poor topsoil with quality donor soil

Figure 37 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral and positive evaluations, which is mostly consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a less positive or more negative impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Replace poor topsoil with quality donor soil	Site 1: on-site	3	0	1.000	2	-1	1
	Site 1: overall	3	0	0.500	1	0	1
	Site 2: on-site	2	0.500	0.500	1	0	1
	Site 2: overall	2	0.500	0.500	1	0	1
	Site 3: on-site	3	0	1.000	2	-1	1
	Site 3: overall	3	0	0.500	1	0	1

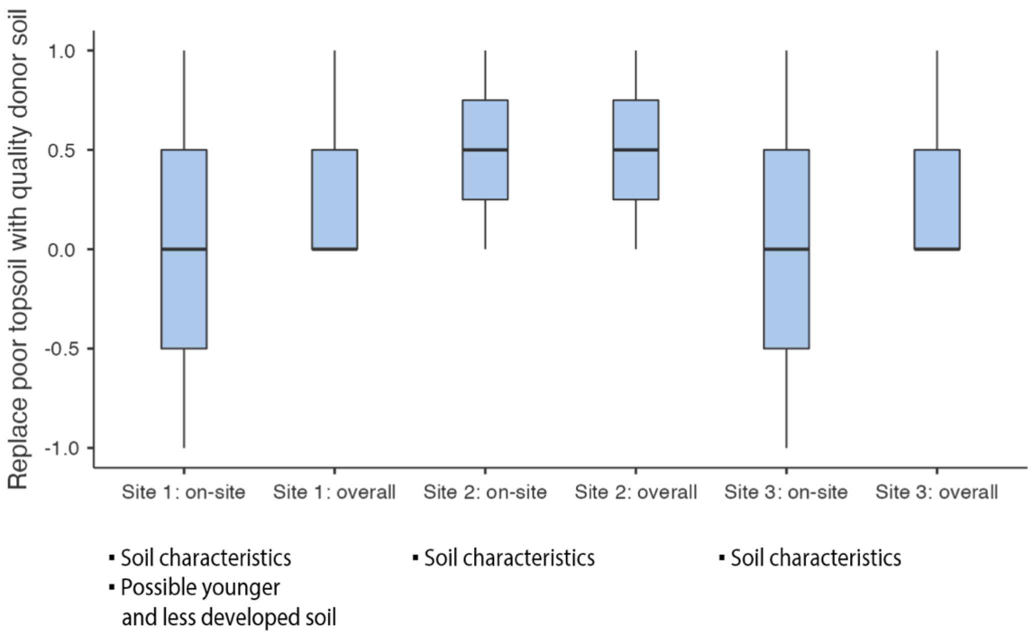


FIGURE 37: REPLACE POOR TOPSOIL WITH QUALITY DONOR SOIL - IMPACT PER SITE

For every site was mentioned that this management action could improve the conditions for habitat creation or restoration and that while it could have a positive effect, it must be connected with an appropriate form of management to prevent overgrowth including broader area.

Contrarily, it was mentioned for Site 1 that as many rare plant species prefer topsoil poor in nutrients, there is no relevant reason for such a measurement; and for Site 3, that it will not enhance the ecosystem quality and that due to possible introduction of invasive plant species, it would be an environmental risk.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Replace poor topsoil with quality donor soil", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Altitude (p=0.049, r2=0.994), whereby the negative estimate suggests that sites with higher altitudes are associated with a less positive impact of this management action on biodiversity.
- Area of the largest rectangular corridor (p=0.012, r2=1), whereby the positive estimate suggests that sites with larger rectangular areas without panels are associated with a more positive impact of this management action on biodiversity.

Although these 2 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were the soil characteristics and the presence of invasive plant species nearby.

5.1.30 Use geotextiles to prevent peat erosion

Figure 38 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral and negative evaluations, which is inconsistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more negative impact on biodiversity within the site than in the surrounding region.

The management action is perceived as less harmful to biodiversity on Site 1 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Use geotextiles to prevent peat erosion	Site 1: on-site	4	0.000	0.500	2	-1	1
	Site 1: overall	4	−0.500	1.250	2	-1	1
	Site 2: on-site	3	-1	1.500	3	-2	1
	Site 2: overall	3	0	1.000	2	-1	1
	Site 3: on-site	4	−1.000	0.500	2	-1	1
	Site 3: overall	4	−0.500	1.250	2	-1	1

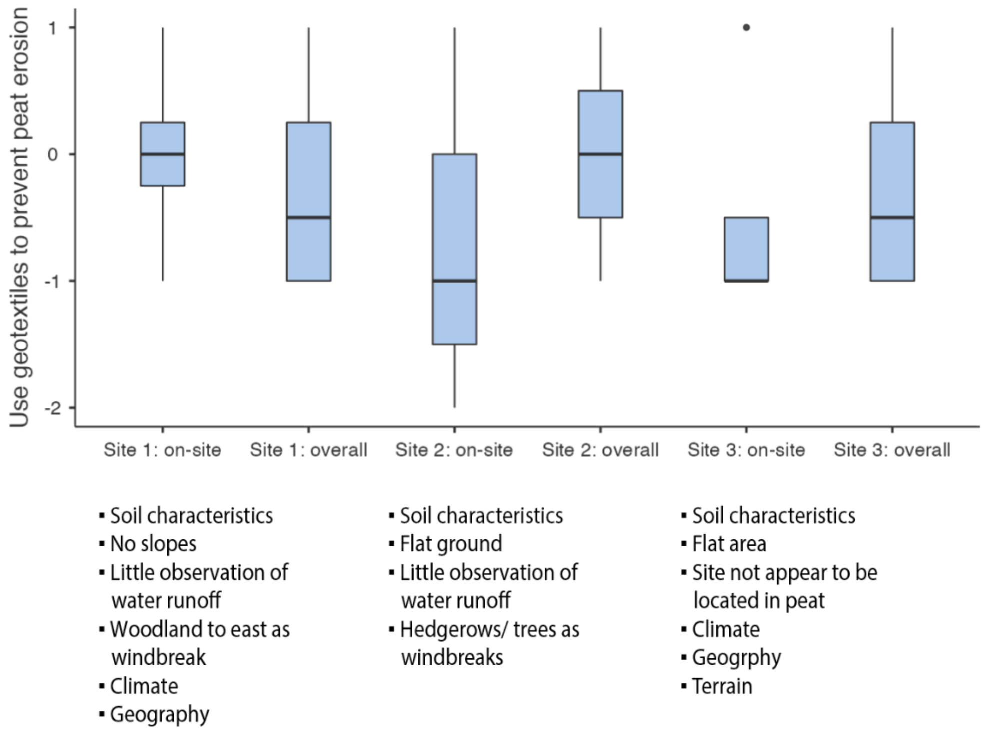


FIGURE 38: USE GEOTEXTILES TO PREVENT PEAT EROSION - IMPACT PER SITE

Although it was considered that this MA could be helpful to reduce erosion and ultimately maintain habitats for biodiversity, most of the experts considered that geotextiles would have a negative impact on biodiversity because they would stop the natural development of habitats; they would have a negative effect to Arthropods; and if they made from plastics, they would pose a source of microplastics in the environment.

Nevertheless, this MA was considered unnecessary due to the characteristics of the terrain and it was mentioned that in case they would be necessary a better solution would be to realise a suitable form of management and establish a wildflower grassland habitat.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: soil characteristics, absence of water runoff, woodland nearby, terrain, absence of peat, climate and geography.

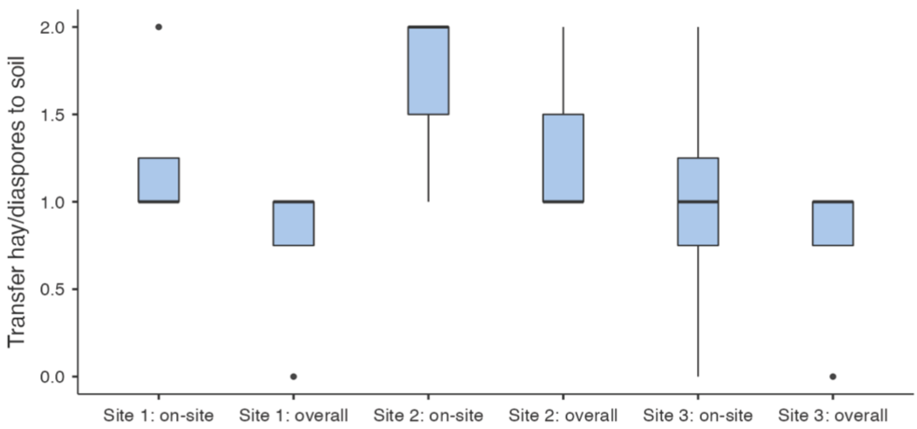
5.1.31 Transfer hay/diaspores to soil

Figure 39 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Transfer hay/diaspores to soil	Site 1: on-site	4	1.00	0.250	1	1	2
	Site 1: overall	4	1.00	0.250	1	0	1
	Site 2: on-site	3	2	0.500	1	1	2
	Site 2: overall	3	1	0.500	1	1	2
	Site 3: on-site	4	1.00	0.500	2	0	2
	Site 3: overall	4	1.00	0.250	1	0	1



- Soil characteristics
- Grassland
- Flowering species on the site
- Site located near areas of grassland habitats withtin PA Bile Karpathy
- Possibly compacted soil
- Climate
- Geography
- Environment

- Soil characteristics
- Grassland
- Site located near areas of grassland habitats within the PAs
- Possibly compacted soil

- Soil characteristics
- Grassland
- No sutaible hay donor from PAs around
- Environment

FIGURE 39: TRANSFER/ DIASPORES TO SOIL - IMPACT PER SITE

According to the experts, this MA could have a positive impact on biodiversity as hay transfer could introduce seeds to the soil and increase floral cover and diversity and even better if it is from the local area and contains a mix of species that suit local conditions. In addition, it was mentioned that the transfer of green hay or diaspores of suitable plant species could be beneficial because of the restoration of original communities.

For Site 1 and Site 2 was mentioned that the use of green hay, for which it may be possible to source from the nearby protected grassland areas, will ensure the introduction of native wild-flower species suitable for the local conditions and could be economically more viable that the use of commercial seed. For both sites was added that as the soil is apparently compacted some topsoil disturbance may be required to enable successful establishment. Furthermore, for Site 1 was mentioned that this MA could enhance the plant diversity when local hey without invasive species is used.

Meanwhile, for Site 3 experts mentioned that from the list of protected areas, none appear to be a suitable hay donor, therefore accessing a nearby species-rich source may be difficult and impractical. However, it was stated that if there would be a good source of flowers rich hey, it could raise the numbers of plant species.

A regression analysis attempted to predict the median "on-site" evaluations for this management action, "Transfer diaspores to soil", using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts' evaluations of the biodiversity impact:

- Altitude (p=0.049, r2=0.994), whereby the negative estimate suggests that sites with higher altitudes are associated with a less positive impact of this management action on biodiversity.
- Area of the largest rectangular corridor (p=0.012, r2=1), whereby the positive estimate suggests that sites with larger rectangular areas without panels are associated with a more positive impact of this management action on biodiversity.

Although these 2 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: soil characteristics, grassland, flowering species in the site, distance from PAs wich could be suitable hay donors, climate, geography and environment.

5.1.32 Allow trees to grow in hedgerows

Figure 40 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Allow trees to grow in hedgerows	Site 1: on-site	4	2.00	0.000	0	2	2
	Site 1: overall	4	1.50	1.000	1	1	2
	Site 2: on-site	3	2	0.000	0	2	2
	Site 2: overall	3	2	0.500	1	1	2
	Site 3: on-site	4	2.00	0.500	2	0	2
	Site 3: overall	4	2.00	0.500	2	0	2

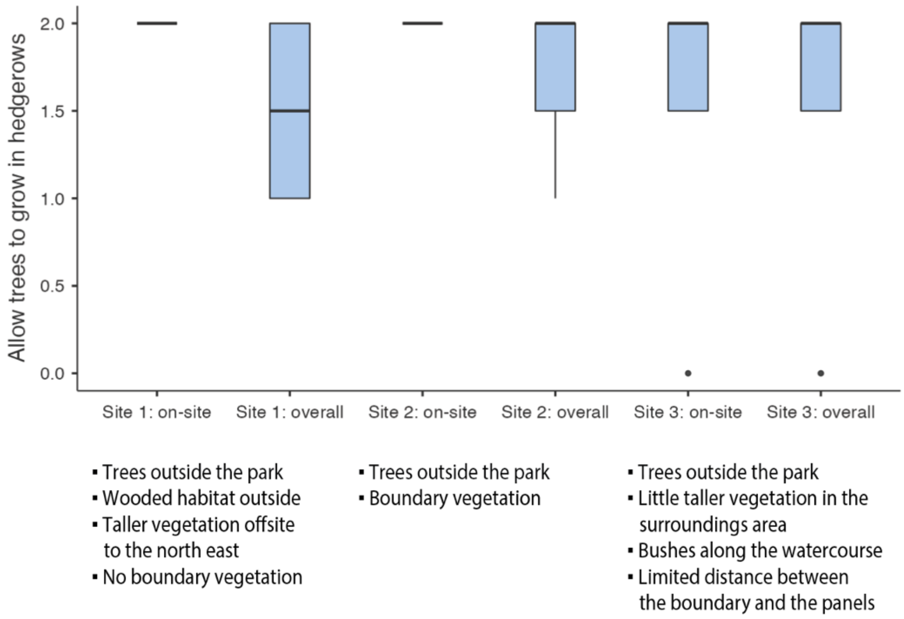


FIGURE 40: ALLOW TREES TO GROW IN HEDGEROWS - IMPACT PER SITE

In general, experts agreed that this management action would positively impact biodiversity because this could increase species richness; provide a habitat for a variety of groups (invertebrates, birds, bats etc.); provides nesting habitats.; increases the diversity of woody vegetation which therefore increases the number of species (in particular insects) that the hedgerow supports; and provide cover and resource of food for many animal species, including individuals from the broader area of PV site. Furthermore, it was mentioned that flowering trees will provide resources for invertebrates and trees that produce berries will provide a food source for birds.

For site 1, according to the experts this MA would support the spatial mosaic on the PV site and compliment the wooded habitat just outside of the boundary. Moreover, it was suggested for this site that putting a vegetated corridor along the northern boundary could complement the taller vegetation offsite to the northeast and create a corridor, although the south east boundary would have more value but would likely shade the panels.

For Site 2 was mentioned that the boundary vegetation at present appears to have ornamental value, rather than ecological value and that the potential of the trees shading the panels would have to be reviewed.

Meanwhile, for Site 3 was mentioned that there are some bushes along the water course which provide some food and nesting niche for birds next door and that since there is little taller vegetation in the surrounding area, this could provide a useful windbreak, but may cause shading especially as the distance between the boundary and panels is limited.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were the wooded vegetation adjacent to the site and the wooded vegetation in the surroundings.

5.1.33 Cut hedges in winter

Figure 41 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive and negative evaluations, which is inconsistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on Site 3 and a more negative impact on Site 1 on biodiversity within the site than in the surrounding region.

The management action is perceived as less harmful to biodiversity on Site 3 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Cut hedges in winter	Site 1: on-site	4	–0.500	3.25	4	-2	2
	Site 1: overall	4	0.500	1.75	4	-2	2
	Site 2: on-site	3	0	2.00	4	-2	2
	Site 2: overall	3	0	2.00	4	-2	2
	Site 3: on-site	4	1.000	1.00	4	-2	2
	Site 3: overall	4	0.500	1.75	4	-2	2

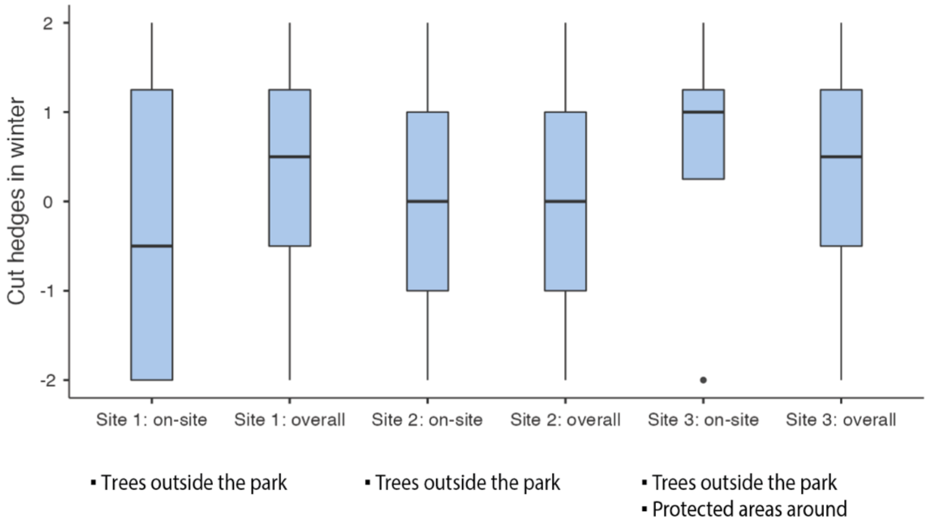


FIGURE 41: CUT HEDGES IN WINTER - IMPACT PER SITE

According to the experts cutting hedges in winter, rather than spring or summer, is beneficial to biodiversity as winter cutting avoids bird breeding season and also prevents flowering plants etc. being removed during the spring and summer. Additionally, it was explained that although winter is the best time of year to cut hedgerows, not all should be cut at the same time, only 1/3 per year on a rotational basis. Other suggestions include cutting free-growing (unshaped) hedges minimally by removing dry branches and controlling growth if needed.

A regression analysis attempted to predict the median “on-site” evaluations for this management action, “Cut hedges in winter”, using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts’ evaluations of the biodiversity impact:

- Distance from a PA that protects flowering plants ($p=0.049$, $r2=0.994$), whereby the positive estimate suggests that sites with longer distances from a PA that protects flowering plants are associated with a more positive impact of this management action on biodiversity.

Although this site characteristic was not mentioned specifically by the experts as relevant site characteristic for the desirability of this management action, as it was found to be significant in the quantitative analysis, it is worthy of further investigation.

Overall, the most relevant site characteristics to evaluate the impact of this management action by the experts were vegetation outside the site and the protected areas in the surroundings.

5.1.34 Maintain low hedges

Figure 42 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between neutral and negative evaluations, which is inconsistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more negative impact on Site 2 and less negative impact on Site 1 on biodiversity within the site than in the surrounding region.

The management action is perceived as less harmful to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Maintain low hedges	Site 1: on-site	4	0.000	0.500	2	-1	1
	Site 1: overall	4	0.000	0.250	1	-1	0
	Site 2: on-site	3	-1	0.500	1	-1	0
	Site 2: overall	3	0	0.500	1	-1	0
	Site 3: on-site	4	–0.500	1.000	1	-1	0
	Site 3: overall	4	–0.500	1.000	1	-1	0

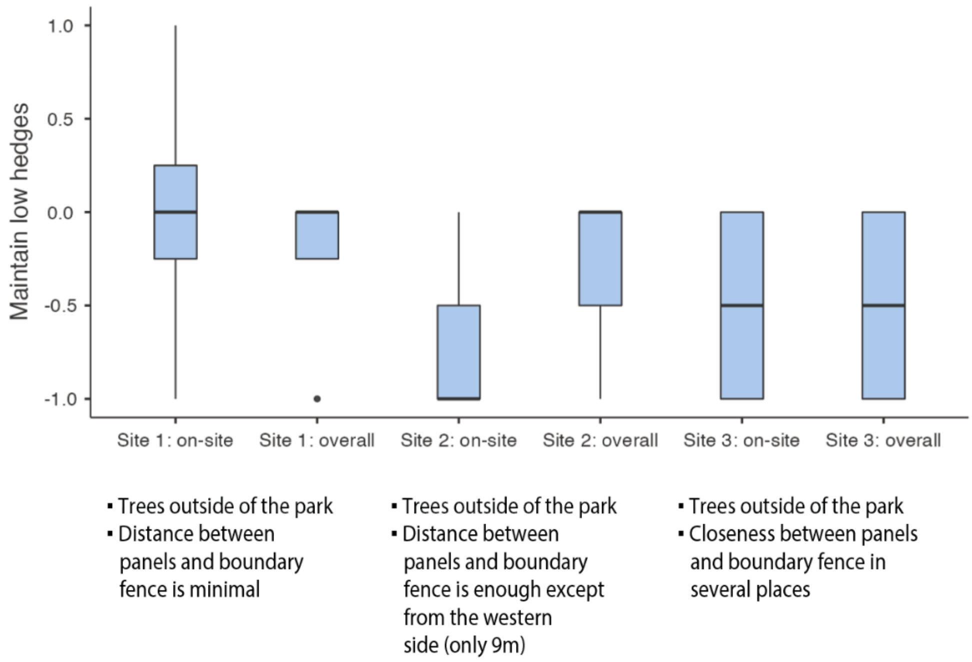


FIGURE 42: MAINTAIN LOW HEDGES - IMPACT PER SITE

It was mentioned for this management action across all sites that the presence/absence of hedges is more important than the height and that maintaining hedges to a certain height might affect species differently, therefore the impact would depend on if the intention is to target specific species with certain requirements.

Nevertheless, it was multiple times recommended a mix of heights as different species prefer different hedgerows' heights and as it would support a higher presence of micro-habitats. The mix of heights was also recommended with the minimum being 1.5-2m. Additionally, the distance between panels and the fence was multiple times considered, explaining that hedgerow height would need to be carefully considered to minimise the risk of shading the panels.

For Site 1 was mentioned that low hedges are not attractive for bird nesting therefore, is better to have hedges higher than 1m and that small hedges can provide shelter for hedgehogs, small vertebrates and ground-living insects. Similarly, for Site 3 it was explained that it is better to grow hedges in higher forms as higher hedges provide better and safer nesting opportunities.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were the distance between panels and boundary fence and trees outside the site.

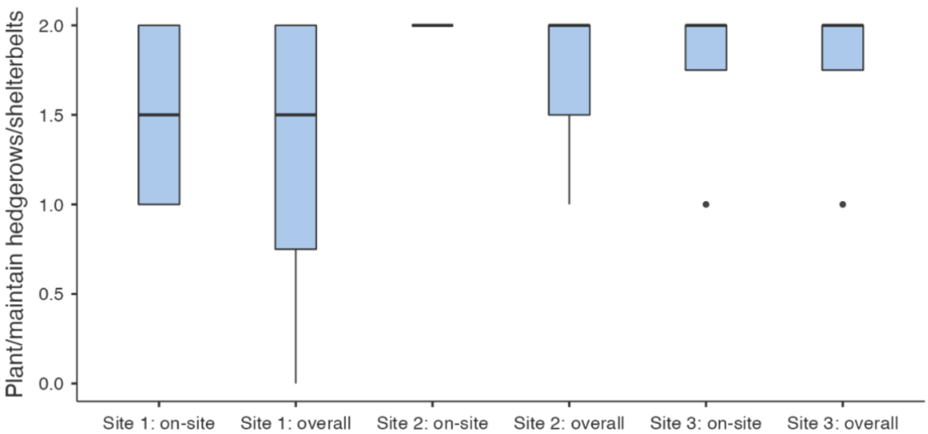
5.1.35 Plant/maintain hedgerows/shelterbelts

Figure 43 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Plant/maintain hedgerows/shelterbelts	Site 1: on-site	4	1.50	1.000	1	1	2
	Site 1: overall	4	1.50	1.250	2	0	2
	Site 2: on-site	3	2	0.000	0	2	2
	Site 2: overall	3	2	0.500	1	1	2
	Site 3: on-site	4	2.00	0.250	1	1	2
	Site 3: overall	4	2.00	0.250	1	1	2



- No hedgerows on this site
- Trees outside of the park
- Surroundings
- Very close to PAs
- Taller vegetation offsite to the north east
- River corridor

- No hedgerows on this site
- Trees outside of the park

- No hedgerows on this site
- Trees outside of the park
- Closeness between panels and boundary fence
- Potential spots in the periphery
- Landscape

FIGURE 43: PLANT/ MAINTAIN HEDGEROWS/ SHELTERBELTS - IMPACT PER SITE

According to the experts, planting and maintaining hedgerows will benefit biodiversity by creating a new habitat type on the site, since none of the sites presented hedgerows, and by providing cover and food resources for various animal species. Moreover, it was explained that this may also increase habitat connectivity on a larger scale if hedgerows could be extended into the landscape. However, experts pointed out, that it is essential to select suitable and native species, that the compatibility with other potential habitats must be carefully considered, and that it may not work for all of the sites' boundaries.

For Site 1, it was specified that planting a hedgerow would complement the taller vegetation to the northeast and river corridor, as well as provide important habitats for numerous insect and bird species. Additionally, it was mentioned that hedgerows can provide shelter for hedgehogs, small vertebrates, and on-ground living insects. However, experts believe that the impact also depends on the species and varieties of hedges planted.

Moreover, for Site 2 and Site 3, it was mentioned that this would greatly increase the ecological value of the sites, introducing woody species that support a large number of insects. It was added for Site 3 that this would extend the nesting habitat for birds in general and that higher trees also provide shelter for bird predators such as sparrowhawks.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were: surroundings, the current presence of wooded vegetation inside the site and the surroundings, distance from protected areas and distance between panels and fence.

5.1.36 Reduce hedge cutting frequency to once every two years

Figure 44 presents the descriptive statistics for the experts' evaluations of the biodiversity impact of this management action for each of the sites. The median figures hover between positive evaluations, which is consistent with the general assessment provided by SPIES (n.d.). It can also be seen that this management action is evaluated as having a more positive impact on biodiversity within the site than in the surrounding region.

The management action is perceived as more beneficial to biodiversity on Site 2 than on the other two sites. The site characteristics mentioned by the experts as influencing their evaluation of the biodiversity impacts of the management action are listed below each of the sites.

Descriptives

	sites	N	Median	IQR	Range	Minimum	Maximum
Reduce hedge cutting frequency to once every two years	Site 1: on-site	4	1.000	2.25	3	-1	2
	Site 1: overall	4	0.500	1.50	3	-1	2
	Site 2: on-site	3	2	1.50	3	-1	2
	Site 2: overall	3	1	1.50	3	-1	2
	Site 3: on-site	4	1.000	2.25	3	-1	2
	Site 3: overall	4	1.000	2.25	3	-1	2

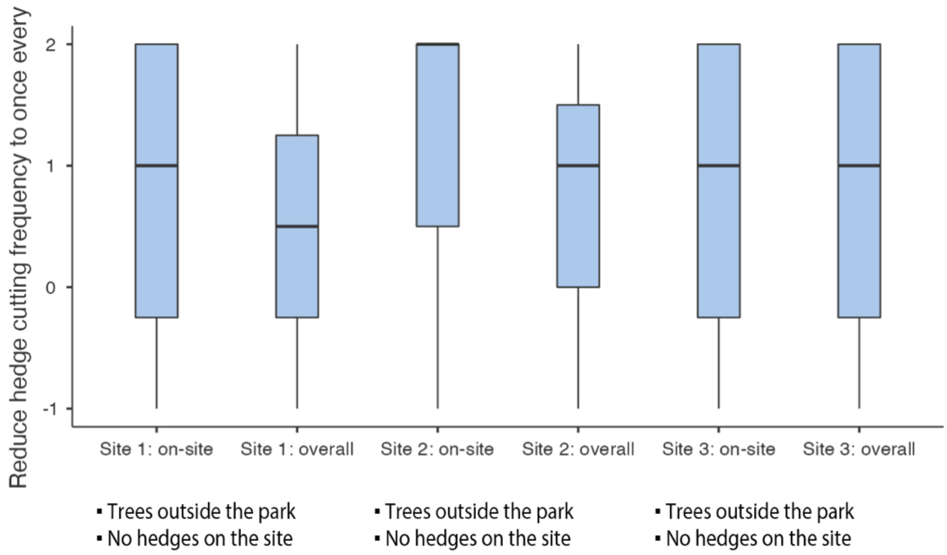


FIGURE 44: REDUCE HEDGE CUTTING FREQUENCY TO ONCE EVERY TWO YEARS - IMPACT PER SITE

Although experts considered that there are no hedgerows in any of the sites, it was mentioned that cutting hedgerows every two years might allow them to become more established and retain some resources offered over the winter e.g., berries for birds. Moreover, it was stated that the timing of cutting would have a higher impact on biodiversity than cutting frequency.

Additionally, some suggestions include:

- Cut hedges on a 2 to 3 year rotation, making sure only 1/3 is cut at any one time to increase the ecological value of the hedgerows.
- Cut free-growing (unshaped) hedges minimally, just remove dry branches and moderate growth if needed.

A regression analysis attempted to predict the median “on-site” evaluations for this management action, “Reduce hedge cutting frequency to once every two years”, using all of the quantifiable site characteristics as predictors. The following site characteristics were found to be significant predictors of the experts’ evaluations of the biodiversity impact:

- Altitude (p=0.049, r2=0.994), whereby the negative estimate suggests that sites with higher altitudes are associated with a less positive impact of this management action on biodiversity.
- Area of the largest rectangular corridor (p=0.012, r2=1), whereby the positive estimate suggests that sites with larger rectangular areas without panels are associated with a more positive impact of this management action on biodiversity.

Although these 2 site characteristics were not mentioned by the experts as relevant site characteristics for the desirability of this management action, as they were found to be significant in the quantitative analysis, they are worthy of further investigation.

Overall, the relevant site characteristics to evaluate the impact of this management action by the experts were the current presence of wooded vegetation inside the site and the surroundings.

5.2 Most biodiversity-beneficial Management Actions for each site

Figures 45, 46 and 47 present boxplots related to the on-site evaluations of all the management actions per site to present the most beneficial and harmful management actions for each site. In addition, a list of the most beneficial and most harmful management actions for each site is provided based only on the following box-plot graphs and the highest and lowest median values. The management actions are numbered in the same way as in the previous sub-section *(5.1 Management Actions and Site Characteristics)* and the *Appendix 1.*

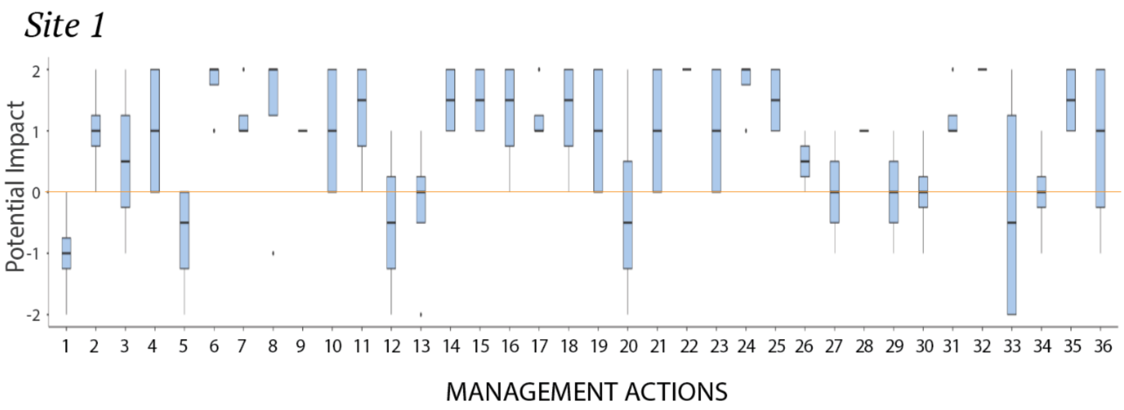


FIGURE 45: POTENTIAL IMPACT OF MANAGEMENT ACTIONS IN SITE 1

The most beneficial management actions for biodiversity in Site 1 are found to be: 6 Mow in strips/patches, spread over time; 22 Plant/maintain wildflowers/nectar seed meadows; 24 Reduce/cease pesticide and fertilizer use if previously used and 32 Allow trees to grow in hedgerows. Meanwhile, the most harmful management actions for biodiversity in this site are found to be: 1 Cease grazing if previously grazed; 5 Cease mowing if previously mowed; 12 Install/maintain subsurface drains; 20 Install/maintain beehives and 33 Cut hedges in winter.

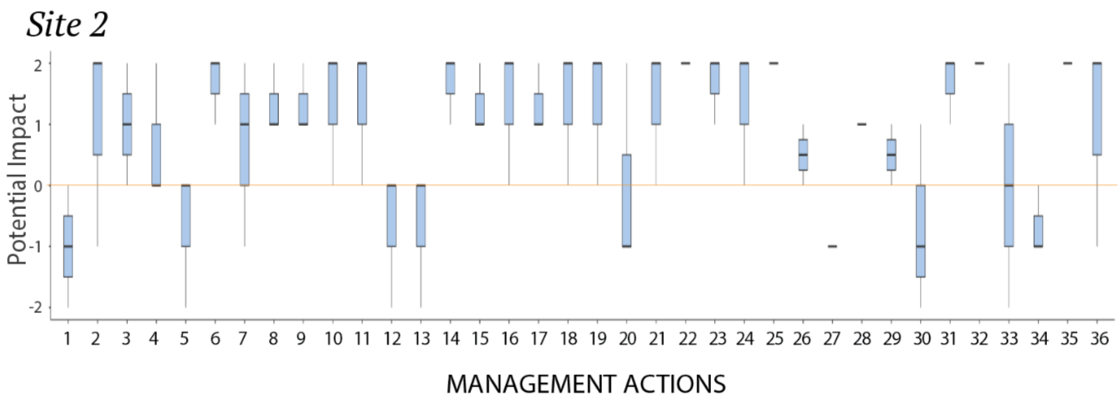


FIGURE 46: POTENTIAL IMPACT OF MANAGEMENT ACTIONS IN SITE 2

The most beneficial management actions for biodiversity in Site 1 are found to be: 6 Mow in strips/patches, spread over time; 14 Connect habitats; 22 Plant/maintain wildflowers/nectar seed meadows; 23 Reduce pollution and green waste inputs into ditches; 25 Create/maintain areas of bare ground; 31 Transfer hay/diaspores to soil; 32 Allow trees to grow in hedgerows and 35 Plant/maintain hedgerows/shelterbelts. Meanwhile, the most harmful management actions for biodiversity in this site are found to be: 1 Cease grazing if previously grazed; 5 Cease mowing if previously mowed; 12 Install/maintain subsurface drains; 13 Install/maintain Sustainable Drainage Systems (SuDS); 20 Install/maintain beehives; 27 Lime soil to adjust pH and increase organic storage; 30 Use geotextiles to prevent peat erosion and 34 Maintain low hedges.

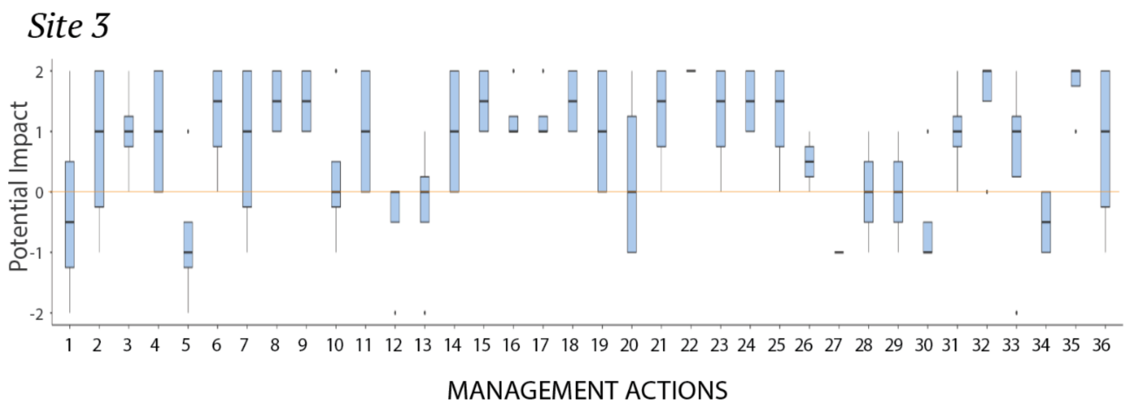


FIGURE 47: POTENTIAL IMPACT OF MANAGEMENT ACTIONS IN SITE 3

The most beneficial management actions for biodiversity in Site 1 are found to be: 8 Reduce mowing regime to once a year; 9 Remove mowing clippings from semi-natural grassland; 15 Create/maintain artificial refugia; 18 Create/maintain buffer zones/field margins/set-aside; 22 Plant/maintain wildflowers/nectar seed meadows; 24 Reduce/cease pesticide and fertilizer use if previously used; 32 Allow trees to grow in hedgerows and 35 Plant/maintain hedgerows/shelterbelts. Meanwhile, the most harmful management actions for biodiversity in this site are found to be: 1 Cease grazing if previously grazed; 5 Cease mowing if previously mowed; 12 Install/maintain subsurface drains; 27 Lime soil to adjust pH and increase organic storage; 30 Use geotextiles to prevent peat erosion and 34 Maintain low hedges.

6 Conclusion

While specific findings for each management action and site are described in the previous section, this section provides general conclusions and recommendations. The limitations of the study are presented and used to derive suggestions for further research.

6.1 General conclusions and recommendations

Overall, the findings of the research confirm the need for decision-makers in PV Parks to consider the characteristics of each site when selecting the management actions to implement, as what may be beneficial for biodiversity in one site could be harmful or have no effect on other sites. Moreover, the findings allow for the recommendations of prioritizing management actions that increase the heterogeneity of wildlife in the PV Park and biodiversity monitoring.

Although most of the results were consistent with the guidance provided by SPIES DST, the results of nine management actions were not *(see Apendix 1: Results overview).* While in this study, the median figures hover between positive evaluations for “remove mowing clippings from semi-natural grassland” and “remove mowing clippings from wildflower meadows”, as these MAs prevent excess nutrients from entering the soil, among other reasons, SPIES evaluate these two MAs as neutral and negative, respectively. Moreover, the management actions related to drainage, “Install/maintain subsurface drains” and “Install/maintain Sustainable Drainage Systems (SuDS)”, are considered positively by SPIES, yet the median expert evaluation values ranged between neutral and negative, mostly due to the lack of need for drainage in the sites with additional comments against all forms of drainage systems in today’s agricultural landscape. Furthermore, the results from the MAs “Reduce pollution and green waste inputs into ditches”, “Lime soil to adjust pH and increase organic storage”, “Use geotextiles to prevent peat erosion”, “Cut hedges in winter” and “Maintain low hedges” were also inconsistent with SPIES DST guide.

The potential biodiversity impact of the management actions varies slightly between the assessments for inside versus outside of the sites. However, none of the MAs was considered beneficial inside while detrimental outside a PV park, or vice-versa. In most cases, the positive or negative impact on biodiversity appears to be stronger inside the site, which is understandable. However, for three MAs, the impact on biodiversity appears to be more positive outside the site than inside, while for one MA appears to be more negative outside the site *(see Appendix 1: Results overview).*

To answer the research question: “What is the relationship between the characteristics of photovoltaic parks and biodiversity impacts of management actions?” because the answers are specific for each management action and each site, *subsection 5.1* discusses in detail which characteristics of each site influenced the potential impact of management actions on biodiversity and how. In addition, a summary of the relevant site characteristics considered for each MA is provided in *Appendix 1: Results overview.*

Nevertheless, one of the interesting findings was that for site 1 experts identified an invasive species outside the site (Solidago sp.) which influenced their impact evaluation of several management actions for this site as they expressed their concerns about the spread of this invasive species. As explained also in the literature review, the spread of invasive species is one of the main drivers of biodiversity loss and therefore is recommended to consider the presence of this species when deciding the management actions to implement. Similarly, the amount of grass species in the sites influenced the evaluations of MA related to cutting regimes, as experts suggested avoiding the spread of grass species and encouraging different types of vegetation to be stablish in the PV Parks.

In addition, the surroundings significantly influenced the experts' answers. For Site 3, for example, as the site is surrounded mostly by agricultural areas, experts expressed their opinion on how some habitat-related MAs may have a greater impact on biodiversity outside the site due to the lack of habitats and how some other MAs could have lesser impacts due to the already homogeneous landscape. Moreover, the proximity to protected areas and the protected habitats and species in these also influenced the potential of some habitat-related MAs as some of these have the potential to support species of interest.

Although specific information about the nutrients in the soil was not provided, experts mentioned this as a relevant characteristic when deciding soil-related MAs and MAs related to the cutting regimes. For instance, although experts considered grazing a more beneficial cutting regime, it was also mentioned that grazing could be less recommended when the soil presents a high concentration of Nitrogen.

The most beneficial and harmful management actions for each site can be observed in subsection 5.2. Similar to the findings from the literature review, the results highlight the need for continued mowing and grazing in all sites, as abandonment could not only pose a threat to energy generation but also to biodiversity. Thus, ceasing grazing and ceasing mowing appear to be the most harmful management actions for Site 1 and Site 2, the two sites that are currently managed by mowing. Moreover, “liming soil to adjust Ph and increase organic storage” and “use geotextiles to prevent peat erosion” were other MAs considered detrimental for Site 2 and Site 3.

Among the most beneficial management actions for all the sites were: “Mow in strips/patches, spread over time”, “Plant/maintain wildflowers/nectar seed meadows”, “Reduce/cease pesticide and fertilizer use if previously used”, “Allow trees to grow in hedgerows” and “Plant/maintain hedgerows/shelterbelts”.

6.2 Limitations and future research directions

While this master's thesis has provided valuable insights into the relationship between site characteristics of photovoltaic parks and the biodiversity impacts of management actions, the complexity of the topic comes with certain limitations as well several paths for future research that can further contribute to the integration of strategies to restore biodiversity into renewable energy systems to address the interconnected challenges of climate change and biodiversity loss.

Firstly, regarding the research method, due to the resources and time constraints, the study covered only a small number of PV parks. While efforts to study PV parks with different characteristics were made, the three PV parks in the study nevertheless shared many similar characteristics, which could have limited the differences between site evaluations. Moreover, as the PV parks studied are located in the same region, this limits the understanding of whether the findings could be applied somewhere else. Similar research in different locations as well as a larger number of PV parks studied could expand the research and provide a greater understanding of the influence of site characteristics on the biodiversity impacts of management action.

While the site visits, use of online sources, and the generous provision of information by *the company* allowed for the creation of comprehensive SCDP for each site, it must be acknowledged that there are always more site characteristic variables that could potentially be measured and considered. For instance, experts mentioned multiple times how the nutrients in the soil, as well as other soil characteristics, could influence the impact of different management actions, including some related to mowing, grazing, drainage and soil. Therefore, additional information about the soil is suggested to be considered for future research.

Similarly, although the site characteristics found in the quantitative analysis as relevant for the desirability of specific management actions differ from the characteristics mentioned by the experts, as they were found to be significant in the quantitative analysis, further investigation could expand the knowledge of this topic (e.g., altitude, distance from protected areas and area of the largest rectangular corridor).

Due to the extensive amount of information presented to the biodiversity experts, and given their own time constraints, the number of expert evaluations was limited. This is not seen as a major limitation, given the relative homogeneity of their responses, yet a larger number of respondents would nevertheless be desirable. Moreover, additional research on the management actions that presented a greater range of answers (e.g., install/maintain beehives) could contribute to a more comprehensive understanding of the biodiversity impacts of management actions.

Furthermore, there was some indication of slight variations in the interpretation of the management actions by different experts. For example, the MA "cut hedges in winter" led some experts to compare this MA with not cutting hedges at all, while others compared this with cutting hedges in another season. With more resources and more time, additional rounds of communication between the researcher and experts could have clarified such issues.

Lastly, additional studies could explore the compatibility between management actions and the possible impact of combinations of management actions. For instance, although this study found that grazing could be incompatible with the creation of ponds or the elimination of the fence to connect habitats, the desirability of replacing grazing with mowing in combination with other management actions is unknown.

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APPENDIX 1: RESULTS OVERVIEW

	Incon-sistency with SPIES	On-site vs Overall	MA	SITE CHARACTERISTICS
1		More nega-tive inside	Cease grazing if previ-ously grazed	Grassland ecosystem, site vegetation, species richness, amount of flowers, distance be-tween panels and proportion of land covered with panels.
2		More positive inside	Graze later in the year	Grassland ecosystem, amount of grass species, invasive species near the site, panels height, location in a protected area, sur-roundings and species richness.
3		More positive inside	Reduce grazing inten-sity if previously grazed	Grassland ecosystem, surroundings, development of unpalata-ble dominant species and vegetation height.
4		More positive inside	Replace mowing with grazing if previously mowed	Grassland ecosystem, surroundings, panels height, distance be-tween panels, proportion of land covered with panels, vegeta-tion height and soil nutrients (although no information about this was available).
5		More nega-tive inside	Cease mowing if previ-ously mowed	Grassland ecosystem, location, surroundings, presence of inva-sive species, vegetation, species richness inside the site and its surroundings, climate and geography.
6		More positive inside	Mow in strips/patches, spread over time	Grassland ecosystem, surroundings, areas without panels, dis-tance between panels, location, flora, climate and geography.
7		More positive inside	Mow later in the year	Grassland ecosystem, surroundings, panels height, invasive spe-cies near the site, distance between panels, amount of grass species, species richness, vegetation, location, climate and ge-ography.
8		More positive inside	Reduce mowing re-gime to once a year	Grassland ecosystem, surroundings, panels height, location and invasive species near the site.
9	Positive re-sults while neutral for SPIES	More positive inside	Remove mowing clip-pings from semi-natu-ral grassland	Grassland ecosystem, surroundings, amount of flowering plants in the site, presence of reptiles, amount of agricultural land in the surroundings, location, fire risk, ecological value of the site, and soil nutrients (although no information about this was avail-able).
10	Positive re-sults while neutral for SPIES	More positive inside	Remove mowing clip-pings from wildflower meadows	Grassland ecosystem, surroundings, location, vegetation and presence of reptiles.
11		More positive inside	Block/remove drain-age ditches or reduce intensity	Structure, location in an agricultural landscape, location, sur-roundings, absence of ditches, absence of excess water/ wet land/ water standing, absence of drains and water bodies in the landscape.
12	Neutral and negative re-sults while positive for SPIES	More nega-tive inside	Install/maintain sub-surface drains	Structure, agricultural landscape, surroundings, soil conditions and aspect, proportion of land covered by panels, flat area, dry area, annual precipitation and absence of wet areas/ excess of water/ standing water.
13	Neutral re-sults while positive for SPIES	similar	Install/maintain Sus-tainable Drainage Sys-tems (SuDS)	Structure, agricultural landscape, proximity of watercourse and pas, site slopes, potential run-off of chemicals from the sur-roundings, absence of erosion hazard, flat area, dry area, and absence of wet areas/ excess of water/ standing water.
14		More positive outside	Connect habitats	Proximity to protected areas, natural habitats bordering the site, homogeneity of the landscape, wooded areas outside the site, location within agricultural areas, location with-in urban ar-eas, location and surroundings.

15		More positive inside	Create/maintain artificial refugia	Species in protected areas nearby, trees outside the park, location, surroundings, presence of lizards inside the site and/ or in the vicinity, and poor agricultural landscape.
16		similar	Create/maintain artificial wetlands or wet features	Location, surroundings, species in pas nearby, species in the locality, waterbodies nearby, and distance from pas that protect amphibians.
17		More positive inside	Create/maintain beetle banks	Location, surroundings, adjacent woodland areas, location inside PA, climate region, areas without panels, and arable landscape.
18		More positive inside	Create/maintain buffer zones/field margins/set-aside	Grassland ecosystem, land use, structure, location, surroundings, size of the site, proportion of land covered with panels, distance between panels and fence, location in PA, location in built-up areas, location in agricultural areas, invasive plant species nearby and climate region.
19		More positive outside	Install/maintain bat boxes	The presence of suitable features (e.g. Older and taller trees or houses) inside the site, the scarcity of bat habitats in the surroundings and the species of interest in nearby protected areas.
20		More negative outside	Install/maintain beehives	The presence of beehives in the surrounding areas, environment, land use, structure and agricultural surroundings.
21		Same	Install/maintain bird boxes	The presence of suitable features (e.g. Older and taller trees or houses) inside the site, homogeneity of the surroundings, land use, structure, protected areas nearby, agricultural landscape, wooded vegetation outside the site and the scarcity of more suitable nesting sites in the surroundings.
22		More positive inside	Plant/maintain wildflowers/nectar seed meadows	Flora, floristic diversity, urban surroundings, agricultural surroundings, location in PA, size of areas without panels, size of the site, land use, and structure.
23	Positive results while neutral for SPIES	More positive outside	Reduce pollution and green waste inputs into ditches	Environment, absence of ditches, location, surroundings and the habitats in the site as well as in the surrounding areas.
24		More positive inside	Reduce/cease pesticide and fertilizer use if previously used	Environment of the sites and their surroundings
25		More positive inside	Create/maintain areas of bare ground	Environment, flora, presence of patches of bare ground, presence of lizards and surroundings.
26		Same	Cut sod	Grassland, vegetation
27	Negative results while neutral for SPIES	More negative inside	Lime soil to adjust pH and increase organic storage	Soil ph. and environment.
28		More positive inside site 1, more positive outside site 3	Remove topsoil	The soil characteristics, soil quality, previous land use, and presence of alien plant species.
29		Less positive or more negative inside	Replace poor topsoil with quality donor soil	Soil characteristics and the presence of invasive plant species nearby.
30	Negative results while neutral for SPIES	More negative inside	Use geotextiles to prevent peat erosion	Soil characteristics, absence of water runoff, woodland nearby, terrain, absence of peat, climate and geography.
31		More positive inside	Transfer hay/diaspores to soil	Soil characteristics, grassland, flowering species in the site, distance from pas which could be suitable hay donors, climate, geography, and environment
32		More positive inside	Allow trees to grow in hedgerows	Wooded vegetation adjacent to the site and the wooded vegetation in the surroundings.
33	Positive and negative	More positive and more	Cut hedges in winter	Vegetation outside the site and the protected areas in the surroundings

	results while only positive for SPIES	negative in-side		
34	Negative re-sults while positive for SPIES	More nega-tive and less negative in-side	Maintain low hedges	The distance between panels and boundary fence and trees outside the site.
35		More positive inside	Plant/maintain hedge-rows/shelterbelts	Surroundings, the current presence of wooded vegetation in-side the site and the surroundings, distance from protected ar-eas and distance between panels and fence.
36		More positive inside	Reduce hedge cutting frequency to once every two years	Current presence of wooded vegetation inside the site and the surroundings.