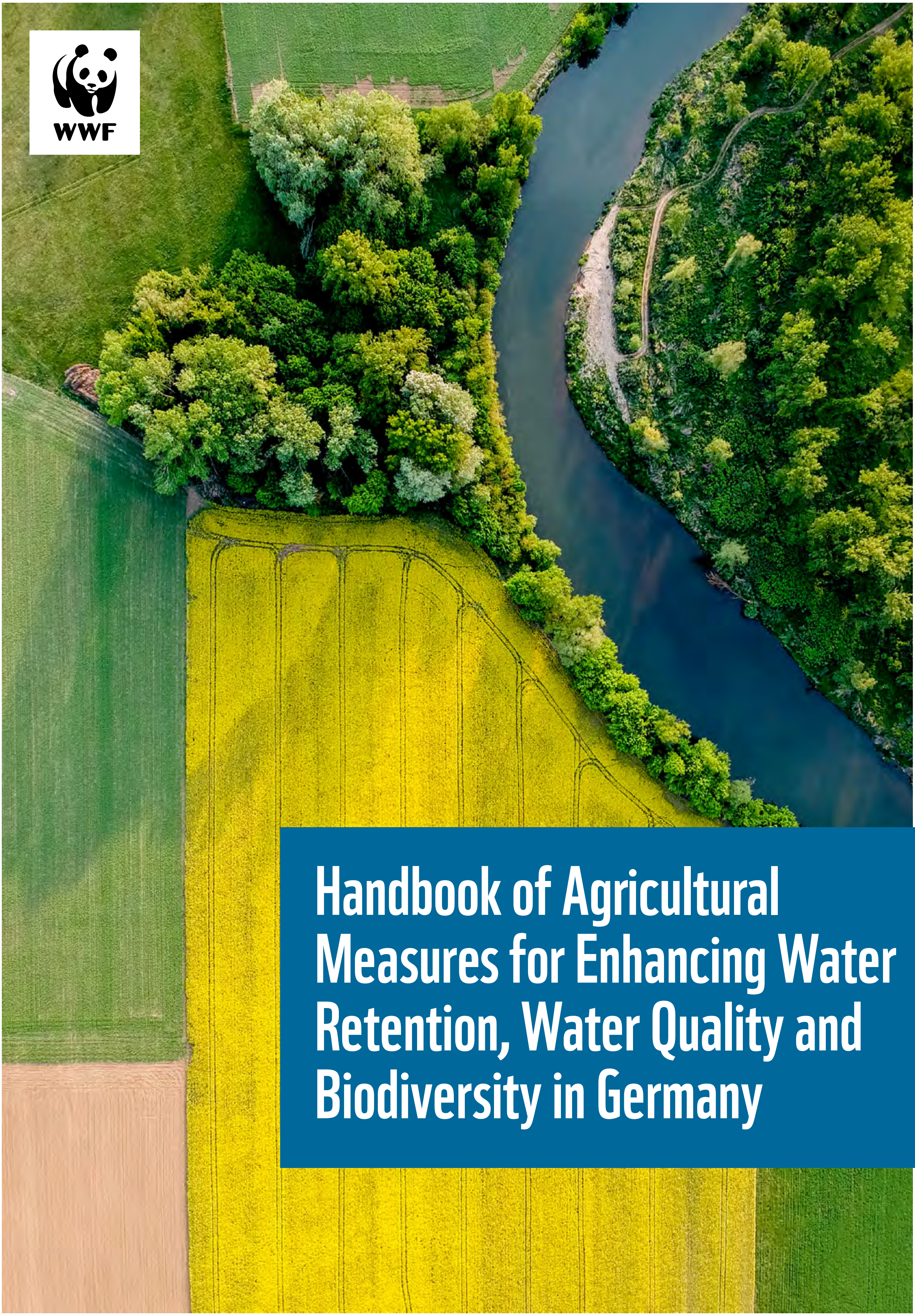

WWF

Handbook of Agricultural Measures for Enhancing Water Retention, Water Quality and Biodiversity in Germany

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Glossary

Börde	A ***börde*** (plural: *börden*) is a region of highly fertile lowland in North and Central Germany.
Field value	Is an index for the quality of arable land from 1 to 100, which is determined in the course of regular arable land assessments.
Field capacity	Field capacity is the amount of water that a water-saturated soil can still hold.
Keyline Design	Adaptation of the planting to the terrain lines to optimize water storage.
Market value	The value is determined according to prices that have been achieved in the ordinary course of business (e.g. sale of agricultural land) for other properties with comparable value-determining factors (Bundesanstalt für Immobilienaufgaben, 2019).
Peat-influenced (anmoor)	Mineral soils that have a high proportion of organic matter (15 to 30 mass %) in the topsoil due to excess water and low oxygen content.
Contribution margins	Output (e.g. through the sale of the harvested crop) minus the variable costs (e.g. fertilizer) (KTBL, 2015).
Services free of direct costs	Output (e.g. through the sale of the crop) minus the costs for the consumption of inputs (e.g. fertilizer) and the use of capital tied up in inputs (KTBL, 2015).

Abbreviations

BNatSchG	Federal Nature Conservation Act (German: Bundesnaturschutzgesetz)
BRB	Brandenburg
BVVG	Soil Utilization and Management Ltd. (German: Bodenverwertungs- und -verwaltungs GmbH)
CAP	Common Agricultural Policy
GAEC	Good Agricultural and Environmental Conditions
Ha	hectare
MV	Mecklenburg Western Pomerania
PPP	Plant protection products
SH	Schleswig-Holstein
ST	Saxony-Anhalt

WEI	Water Extraction Index
WHG	German Federal Water Act (German: Wasserhaushaltsgesetz)
WUC	Water use conflict

Contents

1 Introduction

Figure 1: Pasture with cattle and drainage channel. ©IMAGO/ Olaf Döring.

The way water resources are handled in Germany has changed significantly in recent decades due to changing climatic conditions. While in the past, the focus was primarily on *removing* water from the land in order to make it usable for agricultural purposes, the droughts and aridity of recent years have led to stakeholders in agriculture, forestry and water management wanting to *keep* water in the land. Awareness of the importance of a functioning landscape water balance in Germany has increased considerably. The increase in extreme weather events has highlighted the vulnerability of existing systems: from agriculture to water management infrastructure to ecosystems. Events such as the flood disaster in the Ahr valley (Germany) in 2021 and the increasing frequency of heatwaves and droughts have shown how susceptible both natural and human-made structures are to climate change (BMUV, 2023).

An intact landscape water balance plays a key role in mitigating the effects of climate change.

While soils and the landscape water balance are directly affected by future climate change, functional soils and an intact landscape water balance play a key role in mitigating the effects of climate change. Soils store large quantities of water and therefore have a **water storage function**. This function plays a central role in adapting to climate change (especially in flood protection, buffering extreme precipitation events and improving the water supply for plants). Human activities such as agricultural drainage and hydraulic engineering measures have severely impaired the water storage function. However, agricultural measures can also help to promote the water storage capacity of the soil. It is therefore urgently necessary to identify options for action that promote water retention in the landscape and thus improve the landscape water balance while also protecting biodiversity.

Such options for action must be particularly geared towards creating a closer link between agriculture and water protection. Farmers can benefit from improved water retention measures and better water quality, while their farms are made more resilient to extreme weather events at the same time. By implementing nature-based measures to restore and improve the natural regulating effects of the landscape water balance, farms do not only contribute to the conservation and improvement of natural resources, but also increase their own economic security.

A rich biodiversity increases the soil quality and structure, which in turn increases the water storage capacity of the soil and thus has a direct positive influence on the landscape water balance. While an adequate water supply is essential for the survival of flora and fauna, maintaining biodiversity can also improve the resilience of ecosystems, making them more resistant to drought and heavy rainfall events. For farmers, this means a more stable water supply for their crops and less dependence on artificial irrigation. Additionally, it also supports natural processes such as the pollination of plants and the control of pests.

Against this background, this handbook has been developed to provide farmers, advisors and other stakeholders in agricultural practice with a well-founded and practice-oriented overview of measures to improve water retention, water quality and biodiversity. The aim is to identify practical solutions that can be implemented both at the individual farm level and collectively. **Chapter 2.1** provides an overview of the current **climatic and hydrological situation** in Germany. **Chapter 2.2** explains the current **legal framework** for the implementation and design of agricultural water retention measures. Building on this, **Chapter 3** looks at the effectiveness of various agricultural **measures** that have a positive impact on the landscape water balance and thus also promote biodiversity, which is essential for the functioning of ecosystems. In the course of this chapter, ten individual measures are described in fact sheets, focusing on aspects such as their benefits, cost and potential challenges. **Chapter 4** places the measures from the previous chapter in a **broader context**, using four **example farms**. This shows how these measures can be integrated into existing agricultural practices and their interactions with other local ecological and economic aspects. As the improvement of the landscape water balance cannot only be tackled at field level, **Chapter 5** is dedicated to the scaling of the measures across farms. It includes an outline of **success factors** and strategies for the scaling up of the measures described in the previous chapters in order to make a significant contribution to improving the landscape water balance in Germany.

This subdivision is intended to enable readers to make targeted use of the information relevant to their business or activity and to effectively implement the measures presented.

Figure 2: Catch crop cultivation with phacelia in agriculture. ©IFÖL/Johanna Krähling.

2 Background

This chapter provides contextual information relevant to the future role and importance of nature-based agricultural measures. Chapter 2.1 briefly summarizes the water-related situation for Germany, with overviews of aspects relevant to agriculture such as temperatures, precipitation, conflicts of use and water extraction charge. Chapter 2.2 provides an insight into the legal regulations that are important for nature-based agricultural measures. Chapter 2.3 draws conclusions on the need for action and participation in nature-based measures.

2.1 Water-related situation at the German federal level

2.1.1 Current state of water availability

Analyses of long-term time series already show changes in **temperatures, precipitation and water runoff** over the past decades.

Between 1881 and 2022, the annual average air temperature in Germany rose by a statistically confirmed 1.7 °C, albeit at a significantly higher rate of temperature increase in the last 50 years. Nine of the ten warmest years in Germany were in the 21st century (see Figure 3; Federal Environment Agency (ed.), 2023). The change in air temperatures is particularly evident in the number of hot days (DVGW Deutscher Verein des Gas- und Wasserfaches e. V. (ed.), 2022).

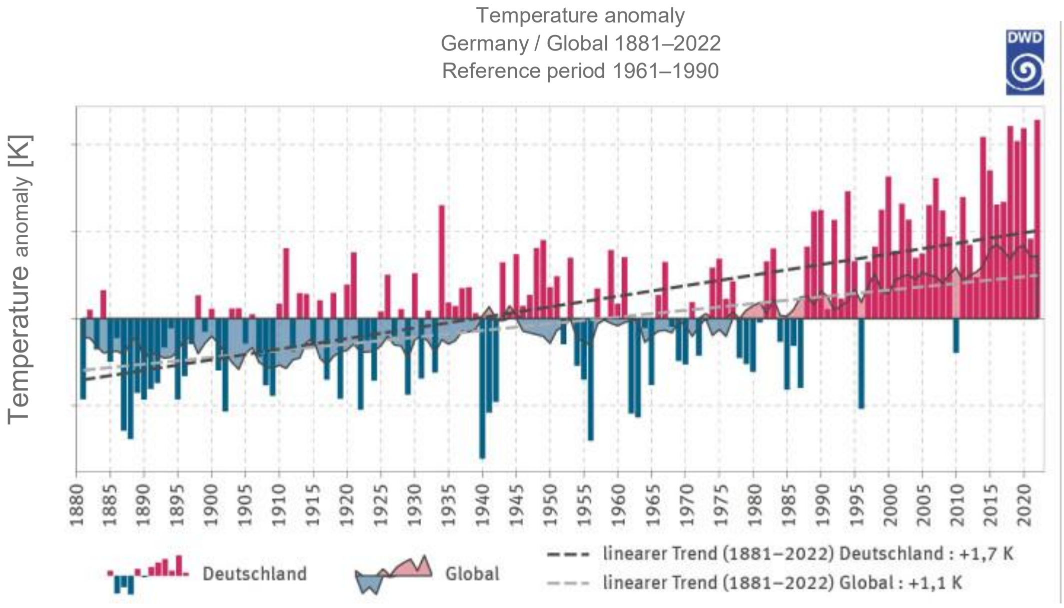

Figure 3: Temperature anomaly. Shown are the deviations of the annual average temperature for Germany and globally from the multi-year average of 1961 to 1990. Source: Monitoring report on the German Adaptation Strategy 2023, ©BMUV/UBA.

Precipitation is also showing an upward trend, which is reflected in winter precipitation in particular. However, precipitation shows a high degree of variability, for example with drier winter half-years in southern and eastern Germany (DVGW Deutscher Verein des Gas- und Wasserfaches e. V. (ed.), 2022).

Since the 1960s, water runoff from river catchment areas[1] has shown a slight decrease in mean runoff for the hydrological winter half-year (start of November to end of April), although this is not statistically significant. In contrast, a significant downward trend can be observed for the hydrological summer half-year (start of May to end of October). The number of low water days in the hydrological summer half-year is increasing significantly, and this increase has been particularly notable since the mid-2010s (Umweltbundesamt (Hrsg.), 2023).

Recent modelling on the topic of **water availability** shows a wide range of results for Germany. These models work with the water extraction index (WEI), which relates regional water extraction to water supply[2]. The water extraction index (similar to the related water use index, see Umweltbundesamt (ed.), 2023)) is used as an indicator of the “water stress” in a region, with a value of 0.2 being interpreted as a critical threshold value and 0.4 as severe water scarcity. Figure 4 shows the results of two modelling approaches: A1 on the left with the mGROWA model and only the total runoff (water supply) occurring on German territory, A2 on the right with the ParFlow model and inclusion of inflows from transboundary catchments. Both models, carried out for the year 2016 in order to avoid temporary distortions due to later dry years, clearly show a different distribution of relative water scarcity in Germany.

For numerous districts, the model results show a water extraction value of between 0.1 and 0.2 (dark green), and a large number of districts also achieve water extraction values of over 0.2, over 0.3 and even over 0.4. The analysis shows that even before the last multi-year phase of drought, water stress is high in many regions of Germany.

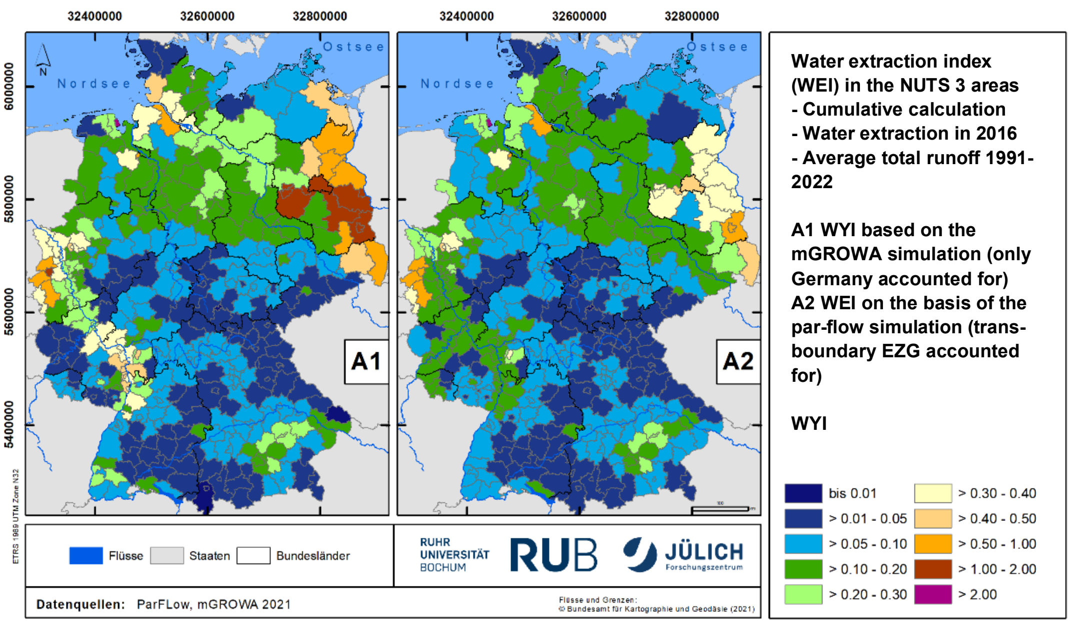

Figure 4: Water extraction index (WEI) in Germany in 2016 calculated on the basis of the total runoff (total water supply) for the period 1991–2020 balanced with the mGROWA and ParFlow models. Source: WADKlim final report, ©Forschungszentrum Jülich.

2.1.2 Predicted development of water availability

Current climate projections consistently show a further increase in air temperature. A current analysis of four major climate projections for Germany (each developed by the DWD, FZ Jülich, KLIWA project and Helmholz Center for Environmental Research UFZ) shows a significant

[1] Runoff is the volume of water that leaves or enters a given catchment area within a certain period of time due to gravity and is essentially made up of surface and subsurface runoff.

[2] Water availability is a parameter of the regional water cycle and comprises the amount of groundwater and surface water that can theoretically be used (Umweltbundesamt (Hrsg.), 2023).

increase in temperatures for all four projections with a narrow projection range (DVGW Deutscher Verein des Gas- und Wasserfaches e. V. (ed.), 2022). According to these projections, both the number of summer days (T ≥ 25 °C) and the number of hot days (T ≥ 30 °C) in Germany will increase significantly across the board. For example, for the period 2031–2060, the DWD projections of the number of hot days show an increase to a median of around 12 days, in the period 2071–2100 even to around 25 days, whereas in the reference period (1971–2000) the number of hot days was around 5 days per year (DVGW Deutscher Verein des Gas- und Wasserfaches e. V. (ed.), 2022).

According to this study, the projections for precipitation and groundwater recharge for Germany are less consistent, which also have a wider projection range than the temperature projections and vary from region to region. Nevertheless, the majority of models show a trend towards **increasing annual precipitation** and **constant to slightly increasing groundwater recharge conditions**, although there is a clear regional variation suggesting low groundwater recharge for some regions in particular. The greatest future challenge is predicted to be the variability, which could lead to an increase in heat, drought, multi-year drought on the one hand and heavy rainfall events and flooding on the other, which could also tend to last longer and be more intense. As a result, it is expected that the management pressure on water resources will be increased, especially in the summer months (DVGW Deutscher Verein des Gas- und Wasserfaches e. V. (ed.), 2022).

Various runoff models as part of the UBA project WADKlim consistently show a decreasing trend for the mean runoff in the summer months, which varies in intensity depending on the model. For the hydrological winter half-year an increase in mean runoff is predicted. According to these forecasts, the dry season will start earlier in the hydrological summer half-year, with the result that the number of low water days in summer will increase significantly (Umweltbundesamt (ed.), 2024).

2.1.3 Impact of climatic developments on sectors and the potential for conflict

The developments outlined above will of course have a significant impact on agriculture. In addition, other sectors and areas are also affected, including drinking water production and the environment. These effects can lead to new or intensified trade-offs and at the same time to an increased potential for conflicts.

Drinking water production is expected to be confronted with greater fluctuations in water availability (runoff rates of flowing waters, water levels in reservoirs, groundwater levels), which may impact resources. These effects would be particularly noticeable for water resources with low natural storage capacity, such as shallow aquifers, wells in rocks with low specific storage capacity and surface waters (Riedel et al., 2021).

A sufficient water supply is essential for the survival of many plant and animal species. The predicted consequences of more frequent droughts and low water events on the environment include, for example, effects on the banks and floodplains of rivers, which are associated with major changes in floodplain vegetation and corresponding effects on birds and other organisms (Kakouie et al., 2018, in Riedel et al., 2021). According to forecasts, these events will also leave their mark on water bodies, such as the reduction in the abundance of macro-invertebrate species by up to 41 % by 2099 (ibid.). In contrast, a stable water balance promotes the creation and preservation of various habitats such as wetlands, mires and forests, which in turn support a high level of biodiversity.

The above-mentioned effects can also impact agriculture, for example as a result of additional water withdrawals by certain sectors (e.g. drinking water production) or restrictions on agricultural water extractions (e.g. a ban on surface water withdrawals to prevent damage to the ecology of water bodies). If water supply declines while demand remains the same or increases, the risk of overexploitation and the potential for conflict between sectors is likely to grow. (Riedel et al., 2021). Studies already show an increase in water use conflicts between users in the recent past. Using a media analysis, the WADKlim project investigated the occurrence of water use conflicts (WUCs) from the 1950s to 2022[3]. Except for the years 2003 and 2006 (characterized by summer heat waves), a maximum of 2 WUCs per year were reported in the years up to 2015. Starting in 2015, regular reporting on the topic has been taking place. Figure 5 shows the frequency of reported WUCs for the period 2015 to 2022. While the frequency of WUC in the years 2015 to 2017 is in the single-digit range, the years 2018 to 2022 show a clear increase (Umweltbundesamt (Hrsg.), 2024).

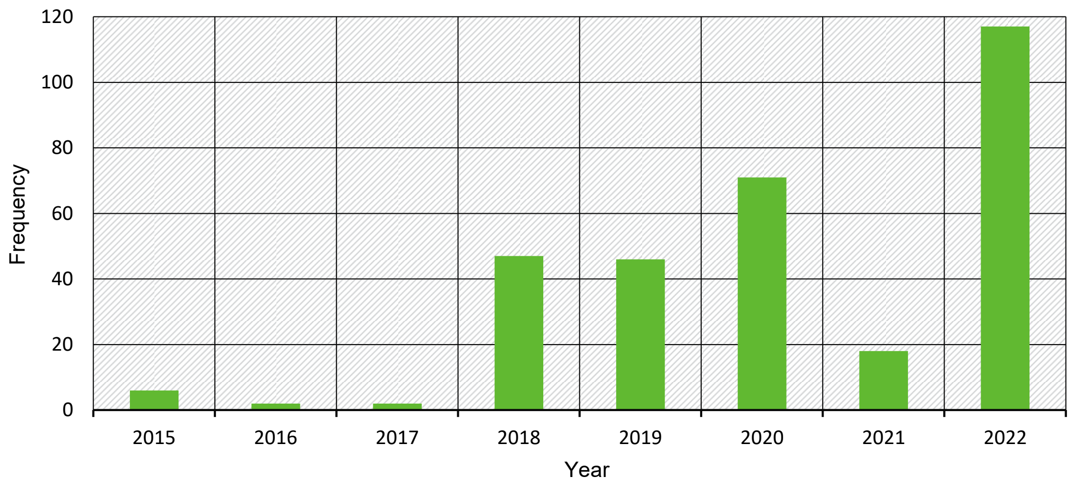

Figure 5: Frequency of WUCs reported in the media in the period from 2015 to 2022. Source: WAD climate final report (Umweltbundesamt (ed.), 2024). ©Ruhr University Bochum.

The increase reflects the climatic conditions of recent years. The years 2018 to 2020 were characterized by drought, with, for example, up to 25 % less precipitation than the reference period 1961–1990 in 2018 (Deutscher Wetterdienst, 2018). In addition, the years 2018 to 2020 were the three warmest years since comprehensive weather records began in 1881 (Deutscher Wetterdienst, 2020). While 2021 was an average weather year overall with sufficient precipitation, 2022 was significantly warmer and drier again with an annual average temperature of 10.5 °C and a precipitation deficit of 15 % in relation to the reference period (Imbery et al., 2023).

As expected, the spatial distribution of the water use conflicts investigated was not homogeneous. Figure 6 provides an overview of the spatial distribution of reported WUCs at district/city level for the entire research period and for 2022 (the year with the highest frequency of reported WUCs). The figure shows that WUCs are not a nationwide phenomenon (for numerous rural districts/urban districs, no WUCs were identified in the entire period under review), but that they occur in specific regions.

[3] It is important to emphasize the limitations of this method, as the corresponding report makes clear: "*At this point, the media information does not enable a complete and bias-free coverage of all WUCs in Germany. They usually only have a limited depth of information and tend to cover conflicts that are visible to the general public (such as low water levels) or that have a direct link to private consumers (such as abstraction bans)*." (own translation of Umweltbundesamt (ed.), 2024).

The analysis over the entire research period (in Figure 6, on the left (A1)) identifies contiguous districts with an increased occurrence of WUCs in the north-east, along the border with Poland, from Upper Lusatia to the Uckermark and in the Spreewald (Germany). Other contiguous NUTS 3 regions can also be recognized in central Germany (from the Magdeburger Börde to the Leipzig Bay and the Thuringian Forest). There are also several NUTS 3 regions in the Lower Rhine, the Rhine-Main area and the Black Forest in which WUCs have been reported.

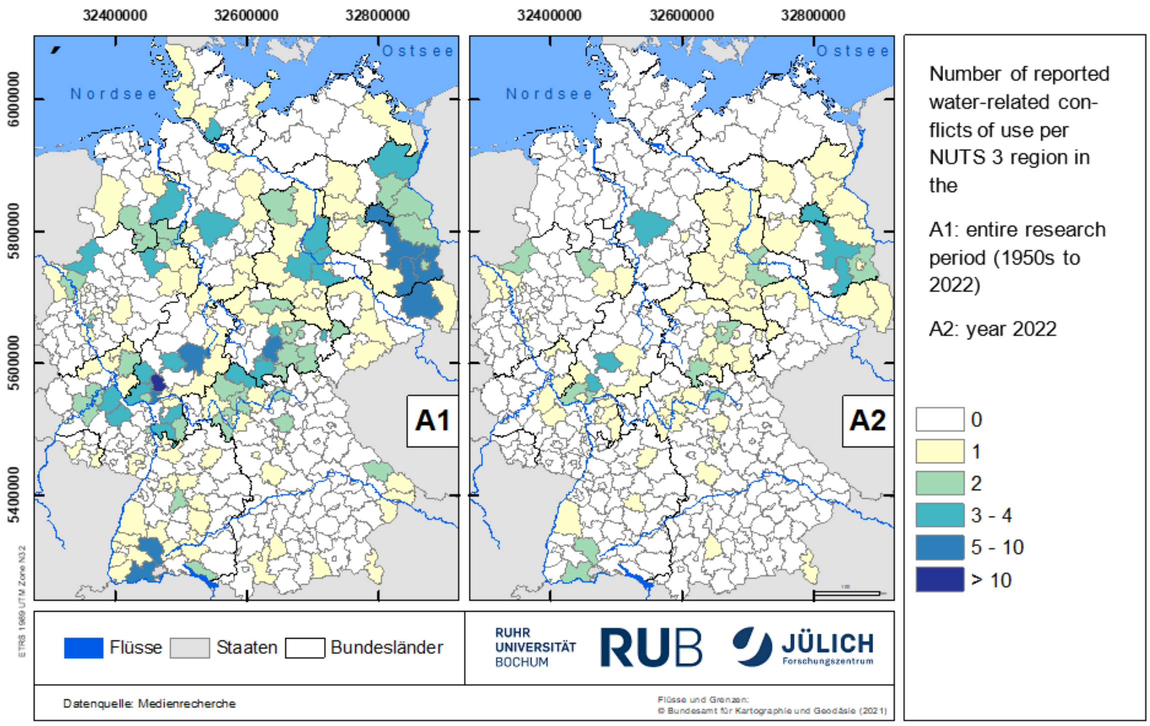

Figure 6: Spatial distribution of the frequency of reported WUCs at the level of NUTS 3 regions in the entire research period (A1) and in 2022 alone (A2). Source: WADKlim final report, ©Ruhr University Bochum.

Even at this stage, a significant involvement of the agricultural sector is already apparent in water use conflicts reported in the media. Figure 7, on the right (A2) shows the actors involved in the water use conflicts, aggregated at NUTS 2 level (usually corresponds to the level of the administrative districts, in some East German federal states the state level). The actors and sectors for which conflicts with agriculture were most frequently reported were “ecosystems” and “private consumers”, followed by “water suppliers” (Umweltbundesamt (ed.), 2024).

The graph also makes it clear that the share of agriculture in water use conflicts is particularly pronounced in the region of central Germany mentioned above, but also in southern Baden-Wurttemberg and along the Rhine in Rhineland-Palatinate and North Rhine-Westphalia (ibid).

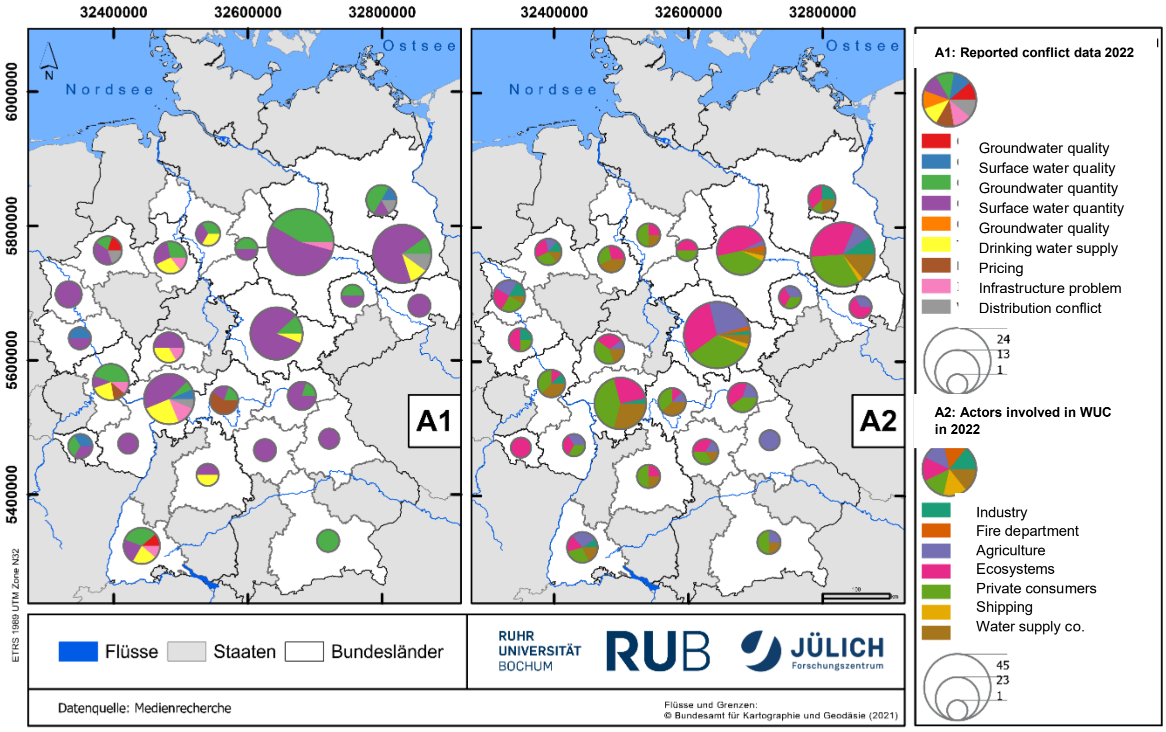

Figure 7: Spatial distribution of conflict types (A1) and actors involved in WUCs (A2) at the level of NUTS 2 regions in 2022. Source: WADKlim final report, ©Ruhr University Bochum.

2.1.4 Pricing of water in Germany

Water extraction charges are currently levied in 13 federal states (Gawel & Köck, 2024). At the time of writing, no charges are levied in Bavaria, Hesse and Thuringia, although an introduction has been announced for 2024 in Bavaria and is currently under review in Hesse (ibid.).

The type of water uses for which a water extraction charge may be levied varies somewhat depending on the water management legislation of the federal state levying the charge. In any case, however, water extraction from surface waters or from groundwater (which is necessary for irrigation purposes) is one of the uses for which charges are levied.

In addition, the charges are differentiated according to areas of use, among other things. In more than a third of the federal states that levy charges, agriculture is exempt from making water extraction charges, while other federal states levy a comparatively low amount for this sector (see Table 1). A complete summary of the water extraction charges, the associated uses and the uses exempt from payments can be found in Erik Gawel and Wolfgang Köck (2024). Table 1 (from BUND, 2019) provides a simplified summary of the water extraction charges levied by different sectors for the abstraction of groundwater. In Germany, groundwater is the most important source for agricultural irrigation: 86.5 % of the irrigation volume comes from groundwater (BMU/UBA, in McNamara et al., 2024).

Table 1: Overview of water extraction charges for the abstraction of groundwater (agriculture, mining, use for cooling and drinking water). Source: "Die Wasserentnahmeentgelte der Länder. BUND brief report" (BUND, 2019).

Costs for the extraction of groundwater

German federate state	Agriculture	Mining industry	Cooling	Drinking water
Baden-Wuerttemberg	0.00 Cent/m³	5.1 Cent/m³	-	10 Cent/m³
Berlin	31 Cent/m³	31 Cent/m³	31 Cent/m³	31 Cent/m³
Brandenburg	-	-	11.5 Cent/m³	10 Cent/m³
Bremen	0.5 Cent/m³	6 Cent/m³	2.5 Cent/m³	6 Cent/m³
Hamburg	16.71 Cent/m³	16.72 Cent/m³	16.72 Cent/m³	16.72 Cent/m³
Mecklenburg Western Pomerania	-	10 Cent/m³	10 Cent/m³	10 Cent/m³
Lower Saxony	0.7 Cent/m³	-	3.7 Cent/m³	9 Cent/m³
Northrhine-Westphalia	-	5 Cent/m³	3.5 Cent/m³	5 Cent/m³
Rhineland Palatinate	-	-	6 Cent/m³	6 Cent/m³
Saarland	12 Cent/m³	12 Cent/m³	4 Cent/m³	10 Cent/m³
Saxony	2.5 Cent/m³	-	7.6 Cent/m³	1.5 Cent/m³
Saxony-Anhalt	2 Cent/m³	-	2 Cent/m³	7 Cent/m³
Schleswig Holstein	3 Cent/m³	-	8 Cent/m³	12 Cent/m³

Source: Die Wasserentnahmeentgelte der Länder. BUND brief report” (BUND, 2019).

These framework conditions should not be regarded as rigid; on the contrary, the law on water extraction charges is “certainly in a state of flux” (Gawel & Köck, 2024). Current trends include, for example, the extension of the obligation to pay charges (ibid.).

In the German National Water Strategy of 2023, the federal government has also taken up the water extraction charge measure as part of the “Water Action Program”. Under measure 11, titled “Further development of water extraction charges and their nationwide introduction”, a “further development of water extraction charges (harmonization and, if necessary, federal regulation) is to be examined”. According to the action program, the charges should not only be earmarked for the implementation of water management measures but should also potentially be designed in such a way that they achieve “a steering effect towards a more conscious use of water as a resource”.

2.2 Legal framework for nature-based water retention measures

The legal framework can also be important for the successful implementation of nature-based water-related measures. Although there are only a few restrictive regulations, official approval may be required for certain measures. On the other hand, there are also opportunities to obtain state subsidies. Some important regulations from the relevant areas of law are summarized below. This is intended to sharpen the focus on which measures can be implemented without further ado – and where a closer examination may be necessary.

The provisions of the German water law are particularly important in this context. Due to the outstanding importance of water for people and nature, they also apply to measures that are carried out on private property and/or have an exclusive effect on private waters. According to Section 37 of the German Federal Water Act (German: Wasserhaushaltsgesetz, WHG), the natural flow of wild water onto a lower-lying property may not be impeded to the detriment of a higher-lying property or increased or altered to the detriment of a lower-lying property.

Section 38 WHG must be observed for measures on riparian buffer strips. This contains a ban on removing trees and shrubs suitable for the location or planting trees and shrubs that are not suitable for the location, which can restrict agroforestry use, among others[4]. Exceptions must be approved by the responsible water authority.

Section 38a WHG also applies to agricultural land with a slope of 5% or more that borders a water body. This stipulates that a 5-metre strip of vegetation must be maintained or established at the edge of a watercourse with closed, year-round vegetation cover. The use of water bodies must always be approved by the responsible water authority in accordance with Section 8 WHG. Near-natural water-related measures can constitute such uses, for example if surface waters are dammed or lowered or if water is diverted from them. The size, duration and type of measure are irrelevant, which means that even small retention facilities and greened drainage systems can be covered[5]. However, there are some exceptions. For example, the mere retention of stormwater runoff does not require a permit. Furthermore, in some federal states, water law does not apply to (human-made) drainage channels, meaning that these can be used (i.e. dammed, lowered, drained, etc.) without further ado.

Figure 8: Drainage channel with buffer strip. ©Unsplash/ Etienne Girardet.

Nature conservation law may also be relevant. According to Section 15 of the Federal Nature Conservation Act (German: Bundesnaturschutzgesetz, BNatSchG), interventions in nature and the landscape are generally subject to compensation. Agricultural use does not constitute an encroachment if it is carried out within the framework of good professional practice (Section 14 (2) BNatSchG). This is assumed to be the case if the objectives of nature conservation are at least taken into account in (commercial) land use. Criteria for the assessment include site-adapted cultivation, a balanced relationship between animal husbandry and plant cultivation as well as compliance with fertilizer and plant protection legislation.

However, the species protection regulations must always be observed (Sections 14, 44 BNatSchG). If, for example, habitats of hamsters, skylarks or other ground breeders are affected by the planting of buffer strips or if protected species are affected by conversion measures, a special permit from the responsible nature conservation authority may be required.

[4] Hübner/Böhm/Zehlius-Eckert (2020): „Rechtliche und politische Hemmnisse für die Agroforstwirtschaft“.
[5] Czychowski/Reinhardt, 13th edition 2023, WHG Section 9 para. 19.

However, the conditions for granting a derogation should generally be met. § Section 21 BNatSchG stipulates, among other things, that surface waters, including their margins, riparian zones and floodplains, must be preserved as habitats and biotopes for naturally occurring animal and plant species. If the measures are to be implemented within a nature or landscape conservation area, the provisions of the respective conservation area ordinance must also be observed.

Nature-based water-related measures can be subsidized by the state under certain conditions. Some of the usual support measures, particularly from the second pillar of the CAP (EU Common Agricultural Policy), provide reference points for this. These include the conversion of arable land into grassland, the enhancement of riparian strips, the creation of buffer strips and near-natural watercourse development. In addition, the current funding period (2023 – 2027) also includes so-called eco-schemes in the first pillar for the first time[6]. For example, the creation of flower strips or flowering areas on arable land or in permanent crops, the cultivation of diverse crops with at least five main crop species or the maintenance of agroforestry management methods are eligible for funding[7]. Funding is limited to one year but can be applied for each year.

There are also numerous subsidized (free or discounted) consulting services on the subject. In any case, it is advisable to find out about existing funding opportunities before implementing the measures. As this is a country-specific law that is subject to constant change, this handbook does not go into this in detail.

Figure 9: Cereal cultivation with accompanying flora. ©WWF/ S. Schröder-Esch.

2.3 Conclusions on the need for action in Germany to implement nature-based measures in the agricultural context

The overview of the water-related situation in Germany in Chapter 2.1 makes it clear that farmers are well advised to adapt to changing weather conditions and changes in water availability. Nature-based agricultural measures, such as those presented in this handbook, can make an

[6] Standardized for Germany in Sections 18 ff. GAPDZG.

[7] Full list in Section 20 GAPDZG; more detailed description in the GAPDZV; see also BMEL: „Den Wandel gestalten! – Zusammenfassung zum GAP-Strategieplan 2023 - 2027“, 20.3.2023, S. 26 ff. and the intervention profiles for the CAP Strategic Plan, available at https://www.bmel.de/SharedDocs/Downloads/DE/_Landwirtschaft/EU-Agrarpolitik-Foerderung/gap-strategieplan-interventionssteckbriefe.html.

important contribution to this. From a legal perspective, there are generally only a few restrictive regulations for nature-based agricultural measures (see section 2.2), although official approval may be required for certain measures.

The benefits of nature-based agricultural measures for farmers include improving the water retention capacity of agricultural soils, which contributes to improved soil moisture (even in dry periods) and a reduced need for irrigation (Beisecker et al., in press). In addition to the purely agricultural benefits of improved soil moisture, there is also a reduced potential for water use conflicts with other stakeholders and sectors (e.g. drinking water supply or fishing associations), as well as reduced irrigation expenditure in federal states where irrigation fees apply. Nature-based measures can also counteract the development of flash floods and flooding, with the reduced erosion benefiting agricultural fields.

Some nature-based agricultural measures also benefit other areas and stakeholders. For example, reduced erosion leads to an improvement in water quality, which benefits both ecology and uses downstream. Improved water retention in the area can also be accompanied by benefits for other areas and stakeholders. It can lead to increased water flow during low water periods and thus to ecological added value for neighbouring ecosystems.

Nature-based measures often also mean disadvantages for farmers, such as adjustments to operating procedures, additional time and additional costs. The other areas and stakeholders that benefit from nature-based measures can, in some cases, be involved in funding the measures. There are also opportunities to receive state funding for some measures.

These topics are discussed in more detail in the following chapters.

Figure 10: Small-structured agricultural area with structural elements. ©Pixabay/ Arno.

3 Measures for Water Retention, Water Quality and Biodiversity

There are already numerous useful publications providing information on agricultural measures that increase soil productivity and biodiversity (see also Gottwald & Stein-Bachinger, 2016; Pingen & Huesmann, 2015, BLE, 2024). With increasing changes to water availability across Germany, as described in Chapter 2, reference works have also emerged in recent years that focus on water retention in the area (see also Botschek et al., 2015; DVL, 2021a; Beisecker et al., 2023). It is in this context that this handbook brings together the most effective measures that, on the one hand, benefit biodiversity and, on the other, explicitly focus on the landscape water balance. While these measures are multifunctional and offer a range of positive ecological and/or economic impacts, the thematic emphasis is on the water-related aspects. This includes both production-related measures such as catch crop cultivation and mulch seeding, as well as landscape features such as riparian buffer strips or vegetated drainage swales.

To ensure the practicability of the following fact sheets of measures, each is placed in a biogeographical context and assigned to a specific regional subdivision that serves the purpose of this handbook. Subsequently, the individual elements within the fact sheets are briefly explained and the bases for calculating economic aspects of measures outlined.

Figure 11: Measures promoting water retention often have a positive impact on biodiversity. ©WWF/ S. Schröder-Esch.

3.1 Geographical division

The success of a measure often depends on the geological, hydrological, biogeographical and pedological conditions at the site. Local weather, soil types and site-specific conditions in a region have a significant influence on the practicability and effectiveness of a measure. In order to address these regional differences, while still maintaining a sense of general validity, Germany has been divided into eight agricultural natural regions for the purpose of this handbook. These are:

(1) North-Western Marsh

(2) North German Plain - West

(3) North German Plain - East

(4) Central German Loess Börde

(5) Central German Uplands

(6) Upper Rhine Rift Valley

(7) South-Western German Scarplands

(8) Alpine Foreland

These are based on the six major natural regions, as well as the demarcation between the biogeographical regions of Germany, namely Atlantic, Continental and Alpine[8]. In addition to weather and geology, other factors that play a major role in the demarcation of different agricultural regions include information[9] on soil types, agricultural use and site-specific yield potential, i.e. the so-called field value. The average soil moisture level of the total soil also varies greatly from region to region and was considered when dividing up the natural areas. This subdivision allows regional peculiarities to be incorporated when applying the measures and will be referred to again in the following fact sheets.

[8] See also: https://www.bfn.de/daten-und-fakten/biogeografische-regionen-und-naturraeumliche-haupteinheiten-deutschlands

[9] See also: BGR soilatlas, map for agrarian use of HU Berlin and the Drought monitor of UFZ.

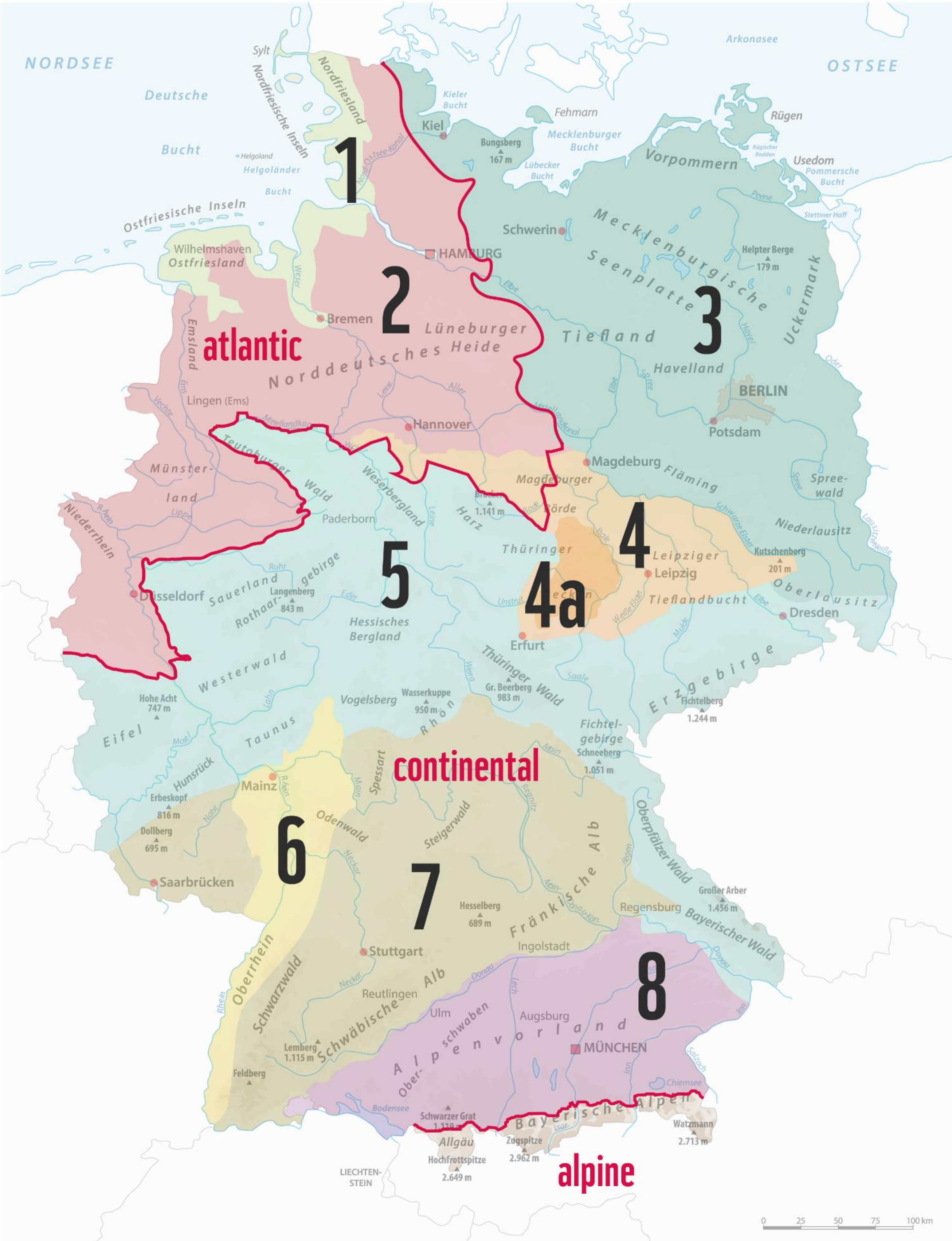

Figure 12: Agricultural natural areas in Germany, including climatic zone subdivisions. ©Ecologic Institute/ Adobe Stock.

(1) North-Western Marsh

Geographical location: The northwestern part of the North German Plain, around the North Sea coast, up to the edge of the Geest regions in Schleswig-Holstein and East Friesland.

Delineation criteria: The region is characterized by the Wadden Sea and an Atlantic climate. Marsh soils are a very fertile and nutrient-rich type of landscape due to the sedimentation of the minerals contained in the water. Therefore they differ significantly from the rest of the North German Plain. A particularly large number of vegetable varieties, sugar beet and potatoes grow in the diked areas.

(2) North German Plain - West

Geographical location: The western part of the North German Plain, starting from the Geest region, stretching to the Dutch border and the Elbe river.

Delineation criteria: This area is characterized by plains and lowlands, with a maritime climate, dominated by bogs, geest landscapes and heathland. Wind erosion contributes to the flat relief. Hydrogeological features include the sandy and nutrient-poor soils of the geest and large riverine landscapes such as that of the Weser river. The main crops are corn and rye, with potatoes and sugar beet being grown in larger quantities in the Lüneburg Heath.

(3) North German Plain - East

Geographical location: The eastern part of the North German Plain, stretching from the Baltic Sea, along the Elbe river to the Polish border, and including the Mecklenburg Lake District.

Delineation criteria: Characterized by sandy soils, hilly landscapes, wide river valleys and forest areas. In terms of geomorphology, glacial forms dominate, while in terms of hydrology, the large lakes and the Baltic Sea coast are of relevance. In contrast to the western part, a more continental climate prevails, which influences the biogeographical conditions and is particularly visible in the map of the site-related yield potential. The region was severely affected by drought in recent years. Due to the large lakes and heath landscapes, the region is home to many nature reserves. In addition to corn, wheat and rapeseed are widely cultivated.

(4) Central German Loess Börde

Geographical location: Central Germany, encompassing the fertile loess areas of Saxony-Anhalt and Thuringia as far as southern Lower Saxony.

Delineation criteria: The region is characterized by highly productive loess soils, flat to hilly landscapes and a temperate climate, which makes it particularly valuable for agriculture. A wide range of crops are grown, ranging from sunflowers, legumes and vegetables to wheat and corn.

Subregion 4a: Central German dry areas with an average annual rainfall below 500mm[10].

(5) Central German Uplands

Geographical location: Comprises the Harz, the Weser Uplands and Sauerland region up to the Teutoburg Forest in the west and extends from the Thuringian Forest and Fichtel Mountains in the east to the Ore Mountains and the Bavarian Forest on the Czech border.

Delineation criteria: Characterized by a more continental climate, mountainous landscapes, dense forests and mountain meadows. Its landscape is marked by numerous springs and river

[10] Dultz, S. (2001). Salzanreicherung in Böden aus Löß im Mitteldeutschen Trockengebiet. In: Huch, M., Geldmacher, H. (eds) Umweltgeochemie in Wasser, Boden und Luft. Geowissenschaften + Umwelt. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-56810-7_1; https://klima.geo.uni-halle.de/mdt_trockengebiet/mdt_raum/.

systems, limestone and sandstone, some with a high proportion of loess. In terms of agriculture, grassland and cereal farming are common.

(6) Upper Rhine Rift Valley

Geographical location: Encompasses the Upper Rhine Rift Valley from southwestern Germany to the French border, as far as the Central German Uplands.

Delineation criteria: The lowlands along the upper middle reaches of the Rhine are considered the warmest region in Germany. The plain was formed by a rift valley, is characterized by very young sediments and high groundwater occurrence. For centuries, specialty crops such as grapes (wine), asparagus and cherries have been cultivated on the fertile soils and the sunny hillsides.

(7) South-Western German Scarplands

Geographical location: Covers southwestern Germany, including the Black Forest and Odenwald, the Swabian Alb and Franconian Alb, extending to the Alpine foothills, but excluding the Upper Rhine Rift Valley.

Delineation criteria: The landscape is characterized by geological structures such as Jurassic limestone and Buntsandstein (specific type of *sandstone*). It features distinct karst phenomena, prominent steep slopes and plateaus that harbor unique ecosystems and large water resources. Crops include corn and wheat as well as grassland, the latter on rather infertile soils.

(8) Alpine Foreland

Geographical location: The strip south of the Danube as far as the Alps (excluding the Alps).

Delineation criteria: This region is characterized by hilly terrain in the foothills of the Alps, interspersed with Alpine meadows. The specific climatic and hydrological conditions, including the river systems and the lake district upstream, are important factors with regard to the water balance. Droughts have been particularly prevalent in this region in recent years. In agricultural terms, grassland, corn and hops dominate.

3.2 Methodology for selecting and describing the measures

For the purposes of this handbook, an overview of 46 agricultural measures was compiled. These were found to have a generally positive impact on water retention, water quality and site-related biodiversity. A list of all measures, including the main evaluation criteria, can be found in Appendix 7.

It is not possible to present the complete evaluation table in a graphical form within the scope of this handbook. The table can be requested from WWF Germany. It includes a brief description and an overview of the sub-measures that show how these agricultural practices are applied across the area. The measures were subdivided and assigned to the following categories:

- Sector (forestry, agriculture, water management)
- Type of measure (nature-based solution, technical, management)
- Application of the measure to individual plots and/or across the whole area
- Time frame for impact [(very) short term, medium term, long term]
- Conflict potential (medium, low, high)

A number of measures are associated with a degree of conflict potential, which is partly based on the costs of implementing and maintaining the measure or the personnel involved. The potential for conflict may also be influenced by possible restrictions on use, competing land use claims and the level of acceptance among those affected.

The effectiveness of the measure was further analyzed in relation to key elements of the landscape water balance:

- Water balance (water supply in dry periods, groundwater recharge, water retention in soil, runoff delay)
- Water quality (erosion control, reduction of nitrogen or phosphate pollution, reduced use of pesticides)
- Biodiversity (biotope networking, species diversity)
- Other effects (flood protection, climate protection, reduced evaporation, synergies between measures)

In this context, the measures are categorized according to their effect. Some have a (highly) beneficial effect on the category, while others have no known effect or even a negative effect.

3.2.1 Overview of the selected measures

All measures on the complete list were prioritized in terms of their impact, leading to the final selection of 10 agricultural measures that have either a direct or indirect impact on the water balance, as well as a positive impact on biodiversity. For agricultural businesses, it is particularly important to weigh up the costs and benefits as well as the specific implementation steps. Therefore, the costs for implementing the measures – i.e. the initial investment costs, the labor costs and the effects on yields – have been roughly calculated. Since this handbook is intended to provide direct support for agricultural businesses, the profiles only include measures that farmers can implement independently on their fields or plots. Larger-scale measures in the open field sometimes have a greater effect on the landscape water balance. However, they often necessitate collaboration with associations, nature conservation organizations or authorities and, in some cases, approval procedures.

These 10 measures represent the most effective and implementation-relevant measures in the agricultural field (the list does not represent *a ranking* in terms of effectiveness or relevance):

1. **Adapted selection of crops and crop rotation**
2. **Reduced soil compaction**
3. **Reduced and conservation tillage**
4. **Agroforestry systems**
5. **Erosion control strips and hedges on field margins**
6. **Riparian and buffer strips in grassland**
7. **Conversion of arable land to grassland**
8. **Vegetated drainage swales**
9. **Small retention areas and small water bodies in the field**
10. **Creation and management of marshy and wet grassland**

3.2.2 Structure of the fact sheets

To provide a quick overview, the **target focus** of the measure (water retention, groundwater recharge, water quality, biodiversity) is highlighted in green on the left-hand side of the fact sheets. It indicates the primary, but not exclusive, function of the measure. The symbol at the beginning of each fact sheet identifies **advantageous geographical locations** in the landscape or farmland where a measure can be even more effective than in others. Nevertheless, all 10 measures are applicable and useful to a certain extent throughout Germany.

This is followed by the actual **description of the measure**, accompanied by a brief explanation of the direct **benefits for farmers**. It also clearly identifies the obstacles and **restrictions from an agricultural perspective**. The **impact of the measure** is described in tabular form for the areas of **water balance, water quality and biodiversity**. The **'Other'** category includes other ecosystem services, such as flood protection, as well as synergetic effects with other measures. The **timeframe** until the impact can be very short-term (< 6 months), short-term (< 2 years), medium-term (2-5 years) or long-term (> 5 years).

In order to make the measure more tangible, the fact sheets each contain brief descriptions of the **implementation** and the associated **cost estimate**. This is based on the calculations, described in the following chapter. All **quotes** stem from practitioners who were interviewed in the context of creating this handbook.

This icon is accompanied by **further information** for farmers, with useful links to practical examples, knowledge resources and contacts.

3.2.3 Basis for the calculation

To calculate the potential of measures, we first created three reference farms to serve as a starting point for the calculations (see Table 2: Overview of reference farms for calculating measures. Source: IfÖL GmbH). As a result, the costs and income of a farm with and without the application of the measure can be calculated. However, this does *not* mean that the measures are only suitable for this type of farm. Instead, we simply selected typical farm structures that are well suited to the specific measure. All three farms represent realistic average types based on current data from the State Offices for Agriculture. In addition, data from the Advisory Board for Technology and Construction in Agriculture (Kuratorium für Technik und Bauwesen in der Landwirtschaft, KTBL), the Federal Ministry of Food and Agriculture (Bundesministerium für Ernährung und Landwirtschaft, BMEL) and the Hesse State Working Group on the Inter-farm Use of Machinery and the Augustenberg advisory aid “Agroforestry Systems for the Production of Valuable Wood” (Landwirtschaftliches Technologiezentrum. LTZ Augustenberg 2020) were used.

In each fact sheet, the **icon** (yellow, blue, green) of the respective reference farm is displayed so that it can be seen at a glance which farm type serves as a reference type.

Reference farm 1 is a conventional arable farm (450 ha) without livestock, with relatively narrow crop rotation and a high yield level. The calculations for the measures “Adapted selection of crops and crop rotation”, “Reduced and conservation tillage”, “Vegetated drainage swale”, “Reduced soil compaction” are applied to this type of farm.

Reference farm 2 is a large livestock farm with 700 ha of land, which is increasingly common in eastern Germany. The farm has 400 dairy cows and female offspring. The proportion of grassland is 30%. Based on this reference farm, calculations are carried out for the measures “Erosion control strips and hedges on field margins”, “Riparian and buffer strips in grassland” and “Conversion of arable land to grassland”.

Reference farm 3 is an organic mixed farm (100 ha) with a diverse crop rotation, a rather low yield level and 40 suckler cows. The measures “Agroforestry systems”, “Small retention areas and small water bodies in fields” and “Creation and management of marshy and wet grassland" are applied to this type of farm in line with its more extensive management approach.

Table 2: Overview of reference farms for calculating measures. Source: IfÖL GmbH

	Farm 1	**Farm 2**	**Farm 3**
Farm Type	**Arable Farming**	**Dairy Farming**	**Mixed Farming**
Location	Saxony-Anhalt	Mecklenburg-Western Po-merania	Hesse
Farm Size (ha)	450*	700**	100***
Farming Method	Conventional	Conventional	Organic
Livestock	None	400 dairy cows + female offspring	40 cows + calves
Crop Rotation	WR-WW-SB-WW	WR-WW-SB-WW	CG-CG-WW-WR
Alternative Crop Rotation	WR-(CC)-FB-WW-(CC)-SB-WW	WR-TR-(CC)-SC-WW-(CC)-ST	CG-CG-WW-CC-ST-SP-WR
Yield Level	High	Medium	Low
Grassland Proportion (ha)	20*	210**	60***
Measure 1	Adapted selection of crops and crop rotation	Erosion control strips and hedges on field margins	Agroforestry systems
Measure 2	Reduced and conservation tillage	Riparian and buffer strips in grassland	Small retention areas and small water bodies in the field
Measure 3	Vegetated drainage swales	Conversion of arable land to grassland	Creation and management of marshy and wet grass-lands
Measure 4	Reduced soil compaction		

* based on the operating results of agricultural enterprises (arable farms) 2022/23 (State Institute for Agriculture and Horti-culture Saxony-Anhalt 2024)

** based on the test farm results (dairy farms) 2022/23 (State Research Institute for Agriculture and Fisheries Mecklenburg-Western Pomerania)

*** based on the accounting results of agricultural holdings 2022/23 (Landesbetrieb Landwirtschaft Hessen 2024)

3.3 The Most Effective Measures: 10 Fact Sheets

3.3.1 Adapted selection of crops and crop rotation

Throughout Germany

Description of measure

Traditionally, crop rotation is based on the concept that plants with varying nutrient and fertilizer requirements are cultivated in a specific sequence to ensure optimal nutrient supply and soil quality (e.g., heavy, moderate, and light feeders). The selection of suitable successive crops enhances soil structure and fertility, such as the cultivation of grain legumes prior to wheat (Alpmann et al., 2014). Crop rotation and well-matched crop sequences also play a significant role in water management. For example, alternating deep- and shallow-rooted plants can improve the soil's infiltration capacity and reduce erosion. Strong synergies can be achieved by combining crop rotation with other agricultural practices, such as mulch seeding (see 3.3.3) or the use of pre- and cover crops. Pre-crop effects also include stabilizing soil crumb structures, which influence the availability of water, heat, and oxygen. Research indicates, for instance, that after the cultivation of clover-grass, the proportion of water-stable soil aggregates exceeds 70%, compared to only 10–15% in soils following root crops (Lütke-Entrup, Kivelitz, 2005).

Figure 13: Broadening the crop rotation with field beans. ©IFÖL/ Johanna Krähling.

Fallow periods in a crop rotation can also play an important role. Since weeds often develop in a growth cycle similar to that of the cultivated plant, a diverse crop rotation can increase competitive pressure on problematic grasses and help suppress them. Additionally, alternating broadleaf and cereal crops, as well as summer and winter crops, has positive phytosanitary effects, such as reducing nematodes, root rot, and beet rot pathogens. This reduces the need for plant protection products, which in turn has positive effects on water quality and biodiversity.

The adaptation of crops and crop rotation involves a large number of sub-measures. The following are just a few examples:

- The cultivation of summer instead of winter cereals, with a preceding catch crop, leads to lower nitrogen levels in the soil during leachate periods.
- Mixed crops, or mixtures of main crops with flowering plants, reduce the risk of nutrient leaching as a diverse plant population can absorb nutrients from the soil more efficiently. Greater floral diversity provides important resources for bees and other pollinating insects.

- Selecting e.g. nitrogen-efficient or drought-tolerant varieties and species can lead to more stable yields and higher nitrogen uptake from the soil during drought periods. The latter reduces the risk of nitrate leaching into the groundwater (see also Beisecker and Seith, 2021). Water-efficient crops such as lentils and soybeans, but also permanent crops such as lavender or rosemary, are becoming increasingly important (BLE, 2023).

"Adapted crop rotation is one of the big topics. It's the only way I can reduce tillage, use of pesticides and fertilization." - Danilo Helm, Agricultural Association Dessau-Mildensee mbH

Benefits for farmers:

In addition to agronomic and economic considerations, improving landscape water balance can also be a reason to diversify crop rotations. Enhanced water retention in the soil increases the availability of water for plants, thus reducing the need for irrigation during drought periods. Over the long term, fertilizer use can also be reduced by including legumes as main or cover crops. Since legumes can fix atmospheric nitrogen, they contribute to a net addition of nitrogen to the farm's nutrient cycle. Crop rotation also positively influences the pressure from diseases and pests, as many pathogens and pests can persist in the soil for several years. Consequently, diversified crop rotations can help reduce pesticide use, leading to cost savings.

Timeframe for impact:
[short term]

Impact

Water balance	Selecting crops with varying root depths significantly improves soil structure, enhancing both the soil's water infiltration and storage capacity. This reduces soil compaction and, consequently, water erosion. The practice has a substantial positive impact on water retention in the soil and the availability of water during dry periods, as plants can more easily draw water upward from deeper soil layers through capillary action. Additionally, the increase in macro- and micropores promotes groundwater recharge.
Water quality	A well-planned crop rotation with fallow periods reduces the need for pesticides and fertilizers, which positively impacts groundwater quality and minimizes the run-off of pollutants into nearby water bodies.
Biodiversity	Diversifying the selection of crops with varying growth heights and densities has a beneficial impact on biodiversity by creating more habitats and nesting sites for birds and small organisms.
Other	The risk of downstream flooding is reduced by increasing the infiltration capacity of agricultural land and building humus through the periodic incorporation of crop and root residues. This is particularly effective when combined with mulch seeding.

Restrictions from an agricultural perspective

- Some farms lack the required technology
- Sales opportunities and profitability of crops must be ensured

Implementation and cost estimate

This approach often involves integrating crops with lower contribution margins compared to an economically optimized crop rotation. Additionally, there are extra costs associated with cultivating cover crops.

For cost estimation, the starting crop rotation consists of winter rapeseed, followed by winter wheat, sugar beets, and another round of winter wheat, with conventional tillage before the rapeseed. To diversify the crop rotation, faba beans and cover crops are integrated before the spring-sown crops, resulting in the following rotation: winter rapeseed – (cover crop) – faba beans – winter wheat – (cover crop) – sugar beets – winter wheat. Over the entire four- or five-year crop rotation, the net returns (excluding direct costs) decrease by approximately €315.00/ha per year after the adjustment. The inclusion of cover crops, sown at two points in the rotation with high-quality seed mixtures, accounts for around €280.00/ha. Using alternative seed mixtures could lower these costs, potentially increasing the net returns (excluding direct costs).

"Catch crops are especially important to us in terms of nutrients, water, and evaporation. We always plant catch crops before summer crops. The field never enters the winter season without vegetation." — Dirk Hopmann, Sandbek Farm

Further information

The cultivation of **diverse crops and crop rotations**, which have a **positive effect on the nitrogen balance** in combination with summer crops and catch crops, has already earned many farmers the title "**WWF Baltic Sea Farmer of the Year**." The award honours farmers in the Baltic Sea catchment area who use protective measures to reduce the discharge of nutrients into the water and thus contribute to the protection of the inland sea. For further information see: http://www.wwf.de/ostseelandwirtin

If you want to learn more about the **cultivation of clover grasses and alfalfa as catch crops**, you will find a large collection of scientific and practical information on cultivation and versatile use at https://www.demonet-kleeluzplus.de/

3.3.2 Reduced soil compaction

Throughout Germany, large-scale impacts in the North German Plain - East

Description of measure

Frequent use of heavy agricultural machinery on farmland can compress the soil's pore structure across large areas, altering the available pore space and reducing the soil's field capacity. Soil compaction is an irreversible process that permanently damages the economic and ecological value of the land. To protect the soil's load-bearing capacity relative to moisture conditions and the frequency of traffic, machinery loads should be adjusted to suit the site-specific conditions. This helps maintain proper gas, water, and nutrient exchange (Ledermüller et al., 2020).

The most important preventative measure is to avoid any form of soil cultivation or traffic while the soil is still too wet. Dry soil has a higher load-bearing capacity.

However, given increasingly variable weather conditions, it is not always possible to fully adhere to these practices. In such cases, tire pressure and the width of the contact area are useful levers to minimize the total weight exerted on the soil. Examples include wide tires, dual tires, reducing tire pressure, or separating field and road transport. Reducing machine weight, such as operating with half-full hoppers, also decreases soil stress (Brunotte et al., 2015). Combining operations, such as integrating primary tillage and seedbed preparation, can reduce the frequency of vehicular traffic and contribute to soil preservation. In *controlled traffic farming* (CTF), all machine loads are confined to permanent traffic lanes over a minimal area. This permanent separation of tracks and cultivated areas optimizes soil use and minimizes disturbances to the soil structure.

- *Controlled Traffic Farming (CTF)* is based on the concept that 80% of soil compaction damage occurs during the first time machinery drives across it. Permanent traffic lanes are designed to enhance water infiltration in the rest of the field. Depending on various factors and local conditions—such as topography and climatic conditions—these lanes can be cultivated or left uncultivated, contributing to erosion control.

Figure 14: Ruts in a field caused by agricultural machinery. ©Pixabay.

"Timing is the most important factor: you should only go out onto the field when the soil can take it. During very long, wet winters, this can of course be a test of patience."
– Dirk Hopmann, Sandbek Farm

Benefits for Farmers

The higher number of macropores in less compressed soils creates good conditions for plant root growth and nutrient uptake, allowing yields to be stabilized or increased. Yield losses in crops that are sensitive to oxygen deficiency are thus avoided (BLE, 2022). Crops benefit from improved water storage capacities, especially in dry years. Less compaction also means less tillage work.

Timeframe for impact:
[Short term]
Impact

Water balance	A site-specific approach to load management helps preserve the volume of soil pores, thereby improving water infiltration. This not only significantly enhances water retention in the field but also supports groundwater recharge. Adequate pore space with high continuity ensures effective air and water movement in the soil, a process largely supported by earthworm activity. These organisms are more prevalent when soil disturbance is reduced, and field traffic is minimized.
Water quality	Greater infiltration in uncompacted soils filters pollutants, thereby protecting groundwater quality. Additionally, surface erosion is reduced, which minimizes pollutant runoff into adjacent water bodies.
Biodiversity	The risk of impairing essential biological and ecological soil functions, and thus degrading the living conditions for soil organisms and microfauna, is minimized.
Other	This measure contributes to flood protection by minimizing runoff peaks during heavy rainfall events. Reduced load input, in combination with strip cropping (see Chapter 3.3.3), can effectively pair decreased soil traffic with smaller-scale cultivation techniques.

Restrictions from an agricultural perspective

- Some farms lack the necessary technology (e.g. tire pressure control system, GPS control) for fertilization and crop protection.
- Limited storage capacity for liquid manure and the time pressure faced by farmers often conflict with the vulnerability of wet subsoils to compaction in the spring.

Implementation and cost estimate

Site-specific load management and the prevention of soil compaction depend on many factors. These include not only the machinery and axle loads used on the farm but also the soil structure and moisture levels at the time of field traffic. As such, it is not possible to provide a cost estimate here. However, for the purchase of a tire pressure control system, costs of approximately €5,000 to €10,000 should be expected, depending on the features (based on research from various suppliers, as of September 2024).

Further information

The BMBF-funded **project SOILAssist** focuses on protecting agricultural soils. It is currently developing a digital communication tool that uses soil data and weather forecasts to assess soil trafficability and coordinate activities among farmers, transport companies, and other stakeholders.

This is based on the useful decision matrices by Lorenz et al. (2016), which help classify the compaction sensitivity of individual fields.

Further information: https://www.soilassist.de/en/topics/optimization-of-management-strategies/decision-matrix-trafficability

3.3.3 Reduced and conservation tillage

Throughout Germany, areas at risk of erosion

Description of measure

Conservation or reduced tillage, also known as low-till farming, is applied to cropland. Soil loosening, such as before sowing, is done more superficially using non-inversion methods (e.g., cultivators, disc harrows). Crop residues are often left on the soil surface. Conservation tillage improves soil health and structure over time, positively impacting the soil's water storage capacity. A specialized form of reduced tillage is strip tillage, where only the area where plants will grow is intensively tilled, while the rest of the soil is left untouched. As a result, at least 30% of soil cover is usually maintained (Demmel, Kirchmeier, Brandhuber, 2012).

Figure 15: Mulch layer on a field. ©IMAGO/ Andia.

This measure combines a variety of practices, including:

- **Muching**: Applying organic material (e.g., green waste, crop residues, compost, straw, leaves, etc.) to cover the soil surface is known as mulching. It can be applied directly to bare soil or around existing plants. Mulching protects the surface from heat and evaporation, helping to retain soil moisture. Additionally, it enhances the soil's water storage capacity and increases humus content, improving soil fertility and health. Mulching can also help suppress weed growth.
- **Mulch seeding**: In mulch seeding, crops are sown directly into the crop residues of the previous main crop. This method avoids plowing and minimizes soil disturbance by using reduced tillage intensity. Crop residues in the topsoil layer are incorporated, creating an airy layer that accelerates decomposition. This promotes higher humus content, enhancing the soil's natural fertility.

“Every tillage operation or intervention in the soil, no matter how small, costs water."

– Danilo Helm, Agricultural Society Dessau-Mildensee mbH

- **No-till sowing**: No-till sowing involves planting crops without prior soil tillage. The high level of soil coverage significantly reduces crusting during heavy rainfall events (LfULG, 2016). It also positively impacts soil life and structure, leading to a substantially higher number of biopores and macropores. This improves the soil's water infiltration and storage capacity. Total herbicides are often used to minimize soil disturbance while avoiding competition from emerging weeds. This negatively affect nature conservation and biodiversity. Additionally, some rare and endangered arable wildflowers rely on a certain level of soil disturbance to thrive.
- Reduced tillage using a skim plow for **seedbed preparation** involves working the soil to shallow depths of 8–16 cm. Crop residues in the top, aerated soil layer are turned under, allowing them to decompose more quickly. This process increases humus content, enhancing the soil's natural fertility.
- Reduced and conservation tillage as part of **post-harvest management**, for example after rapeseed, grain legumes, or corn, aims to reduce nitrogen leaching (LWK Niedersachsen, 2023).

Figure 16: No-till drill. ©IMAGO/ Countrypixel.

Benefits for farmers:

Increasing humus content through the application of organic material can enhance soil fertility and, over time, reduce the need for fertilizers. Improved water infiltration capacity also strengthens crop resilience to drought and reduces the risk of erosion during heavy rainfall events. In no-till farming, the reduced working depth compared to regular plowing requires less tractor traction, leading to fuel savings. Additionally, shallow soil disturbance, such as after rapeseed harvest, prevents the burial of spilled seeds, reducing the likelihood of pronounced secondary dormancy (BLE, 2023).

Timeframe for impact:
[medium term]

Impact

Water balance	Improved soil structure significantly enhances the soil's water retention capacity. The increased absorption ability of the topsoil slows surface runoff, reducing soil erosion and promoting greater infiltration, which supports groundwater recharge. This measure also positively impacts water availability during drought periods.
Water quality	The risk of nitrogen pressure is notably reduced, as the overall mineralization rate decreases, particularly in early spring during the start of the growing season. This is due in part to reduced aeration and slower soil warming (Amelung et al., 2018). While delayed surface runoff and reduced nutrient leaching protect nearby water bodies, the increased use of pesticides becomes essential, which can negatively impact water quality.
Biodiversity	The measure has a positive effect on soil life and biodiversity. It also contributes to habitat connectivity, as increased soil coverage through mulching ensures continuous corridors and habitats for small organisms. However, the elevated use of pesticides may have direct and indirect effects on wildlife and plant communities, such as disrupting food chains.
Other	Plowing releases significant amounts of carbon dioxide, which means that reduced tillage contributes positively to emissions reduction and climate protection. On the other hand, there is an increased risk of nitrous oxide emissions, which can occur due to inadequate soil aeration. This measure is also relevant for flood protection, as it counteracts soil compaction, thereby reducing rapid surface runoff and peak flow rates.

Restrictions from an agricultural perspective

Increased use of pesticides is required (to prevent weed growth, fungal infections, etc.), creating a conflict with political goals aimed at reducing pesticide usage.

- Limited practical applicability in organic farming
- Lack of access to suitable equipment on some farms (e.g., no-till drills as shown in the images above).

Implementation and cost estimate

If reduced tillage is implemented in addition to the adjusted crop rotation described in section 3.3.1, the net return (excluding direct costs) decreases by approximately €100.00/ha per year. In this calculation, lower seeding costs are offset by reduced yields and higher expenses for pesticides. However, the cost of cover cropping in this scenario drops from €280.00/ha to around €150.00/ha when using the same seed mix, as prior tillage operations (disc harrow and cultivator) are eliminated.

Further information

The Open Agrar information platform serves as the shared archive for research institutes under the BMEL, such as the Thünen Institute. In addition to numerous conference papers, journal articles, and other resources, it offers an interesting collection of publications on post-harvest management and field hygiene as integral components of conservation tillage.

Further information: https://www.openagrar.de/servlets/solr/find?version=4.5&condQuery=Nachentemanagement

3.3.4 Agroforestry systems

Throughout Germany, regions at risk of wind erosion, areas with predominantly pasture farming (Alpine Foreland, Northern German Plain)

Description of measure

Agroforestry or tree-field farming are multifunctional land-use systems where the same area is managed with a combination of woody plants and crops (silvoarable systems) and/or livestock (silvopastoral systems). Examples include windbreak hedges, Knicks[11], (short-rotation) alley cropping systems, or orchard meadows. The roots of the woody plants penetrate deeper soil layers than crops, having a strong positive impact on local water infiltration and retention (DVL, 2021a). These systems are often established in straight rows of trees or shrubs, with row spacing designed to accommodate the working widths of agricultural machinery. Depending on the agroforestry system, the tree canopies may close over time, partially shading the crops. This significantly reduces evaporation and provides shelter for livestock as well as habitats for insects and beneficial organisms. Due to its numerous economic and ecological benefits, along with its contribution to enhancing the landscape, agroforestry is gaining increasing popularity.

Figure 17: Silvopastoral agroforestry system. ©WWF/ Sonja Ritter.

Benefits for farmers

Agroforestry systems provide an opportunity to diversify a farm's income sources by producing not only arable crops such as grains but also wood, fruits, or nuts. When combined with livestock, additional products like eggs can also be generated. Moreover, woody plants in fields can improve the microclimate, helping to stabilize yields.

[11] In Schleswig-Holstein, a "Knick" refers to a hedge growing on an earthen mound (also known as a "Wallhecke")

„I think agroforestry is an exciting measure, both with grazing as a silvopastoral system and in combination with arable crops. However, implementation takes courage.“

– David Henke, Farmer in Brandenburg

Timeframe for impact
[medium term]
Impact

Water balance	Due to reduced wind speeds and lower temperatures near tree strips, the relative humidity in these areas is often higher. This leads to decreased evapotranspiration from crops and soil (DVL, 2021a), resulting in less dry soil with greater water absorption capacity. Enhanced root penetration in the soil significantly improves infiltration and water storage capacity. Rain interception by the tree canopy slows surface runoff, greatly reducing erosion. However, it can also lower water availability beneath the canopy.
Water quality	The deeper roots of woody plants can capture phosphorus and nitrogen that are not absorbed by crops and would otherwise leach into the groundwater, mitigating pollution caused by nutrient runoff.
Biodiversity	Agroforestry systems enhance landscape structural diversity, with significant positive effects on local biodiversity. They provide habitats and breeding grounds and enrich food sources for pollinating insects and bird species. Additionally, they foster greater diversity in soil organisms throughout the system.
Other	As natural carbon sinks, woody plants contribute to climate protection. Improved soil pore structure near the trees also creates a sponge-like effect, beneficial during floods. Agroforestry can be effectively combined with strip cropping or the establishment of riparian buffer strips.

Restrictions from an agricultural perspective

- Competition for land use: Crops cannot be grown on the area occupied by woody plants.
- Decision must be made with a long time horizon in mind.
- Planning and implementation are complex, so consulting services are advisable.
- Costly in terms of initial planting and maintenance.
- Yields take several years to materialize.
- Partially unclear legal situation, especially when combined with other funding programs.

Implementation and cost estimate

The costs of agroforestry systems consist of one-time establishment costs (including planting material and planting labor), maintenance costs (e.g., controlling companion vegetation, pruning), and harvest costs. This example calculation is based on the cultivation of high-value timber.

Assuming a lifespan of 60 years and a planting distance of 15 meters, revenues from high-value timber and firewood amount to approximately €18,000/ha. This is offset by establishment, maintenance, and harvesting costs totaling around €4,500/ha, as well as yield losses from the area no longer used for arable farming, amounting to approximately €4,200/ha over the entire lifespan. Compared to "traditional arable farming," the net returns (excluding direct costs) amount to around €9,300/ha over the entire lifespan, equivalent to €155/ha per year. However, it should be noted that revenues are only realized after 60 years, and uncertainties in pricing at such a distant future point must be taken into account.

For other woody components, the results would differ. For example, poplar cultivation for wood chip production is less expensive to establish, and the first revenues (albeit significantly lower than those from high-value timber production) can be realized after about six years of rotation. Poplar cultivation is well-suited for use in silvopastoral systems, such as in combination with poultry farming.

Further information

The **German Association for Agroforestry (DeFAF)** e.V. provides extensive support to its members in implementing agroforestry practices. Through the **Agroforestry Map**, interested farmers can register or search for agroforestry areas, service providers, and research institutions.

More information is available at: https://agroforstkarte.agroforst-info.de/.

Agroforestry systems are also gaining popularity in **poultry farming**, as chickens, being originally forest dwellers, benefit from sufficient cover and thickets in their outdoor areas. The **Lignovis GmbH** offers more details on this topic here: https://www.hühner-wald.de/.

Additionally, farmers in **Hesse, Saxony, Brandenburg, and Baden-Württemberg** are collaborating under the WWF project **"KOMBI – Protecting Biodiversity Together"** to establish agroforestry systems and enhance habitat diversity.

Figure 18: Agroforestry rows with sheep pasture. ©WWF/ Alexander Paul Brandes.

3.3.5 Erosion control strips and hedges on field margins

Central Uplands, South-Western German Scarplands, Upper Rhine Rift Valley. On areas at risk of erosion (slope >15%)

Description of measure

Erosion control strips are areas with natural vegetation (grass, shrubs, or scattered trees) located along the edges of cropland and watercourses. These strips, which are at least five meters wide, are not fertilized and serve as a buffer strip. They can feature various forms of vegetation, ranging from simple grass to combinations of grass, trees, and shrubs. Natural re-growth is unsuitable due to the dominance of weeds often present. Erosion control strips are particularly effective on slopes, where they help reduce soil erosion. By trapping sediment particles in their vegetation, these strips decrease the runoff of nutrients and pesticides from agricultural land into surrounding ecosystems (Ingenieurbüro Lenz, 2017). Buffer zones and hedges also create new microhabitats, contributing to improved landscape structure and aesthetics. When establishing wider borders along fields and paths, sowing wildflower-rich meadow mixtures can create species-rich, interconnected habitats (Gottwald & Stein-Bachinger, 2016).

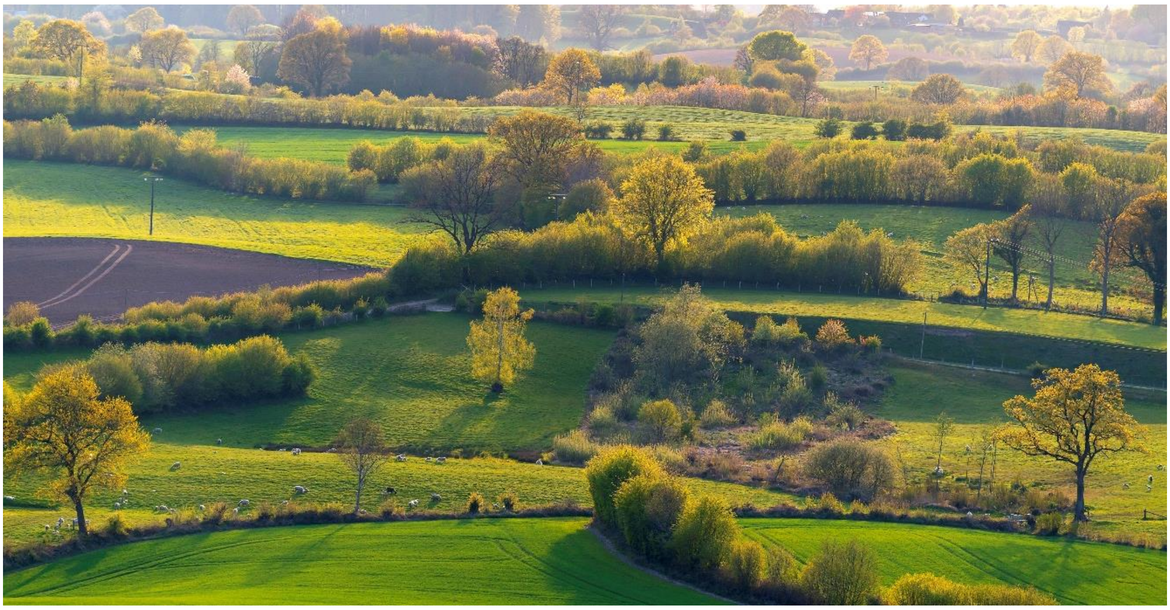

Figure 19: Hedges between arable fields. ©IMAGO/ Blickwinkel.

Benefits for farmers

The measure helps prevent the loss of valuable topsoil caused by wind and water erosion. Additionally, erosion control strips and hedges can serve as habitats for beneficial organisms, positively impacting cultivated crops. This measure may also be relevant for subsidy programs that support small-scale field structures.

“We have enclosed the plant nursery with hedges on three sides, which creates a milder microclimate. This promotes a good balance of pests and beneficial insects, especially in combination with flowering areas.“ – Dirk Hopmann, Sandbek Farm

Timeframe for impact:
[short term]

Impact

Water balance	Erosion control strips on field margins with predominantly permanent vegetation provide excellent conditions for effective water infiltration and reduced surface run-off.
Water quality	**Erosion control strips** significantly decrease the entry of fertilizers, herbicides, and other substances into adjacent water bodies (Ingenieurbüro Lenz, 2017).
Biodiversity	**Hedges and Knicks** create habitats for various animal and plant species, contributing to increased biodiversity. Buffer strips designed as flower strips can also attract a wide range of insects (Gottwald & Stein-Bachinger, 2016).
Other	By slowing surface runoff, erosion control strips contribute to flood protection. The continuous vegetation cover reduces the risk of water erosion during floods. Additionally, hedges are an effective tool against wind erosion, particularly when combined with extensive grazing systems or converting arable land into grassland.

Restrictions from an agricultural perspective

- Loss of productive agricultural land
- Temporary cultivation restrictions on the land due to nature conservation requirements
- Hedges/Knicks can cause competition for water and nutrients with surrounding crops.

Implementation and cost estimate

The calculation of this measure is based on the assumption that an extensively used permanent grassland strip is established on arable land. The costs reflect not only the lower market value of the land due to the loss of arable status in the erosion control strip area but also significantly lower returns for extensively managed grassland compared to arable land.

In total, this results in costs of approximately €25,500.00 per hectare of erosion control strip. Assuming an erosion control strip measuring 6 meters wide and 100 meters long per hectare, this equates to approximately €1,500.00 per hectare of total farmland.

Further information

The company ecodots develops so-called ecopoints (Ökopunkte) and offers attractive remuneration for the utilization of hedgerows and Knicks. The company helps with the construction of the systems in line with their slogan “Living fences for your land” and thus contributes to the preservation of the erosion hedges typical of Schleswig-Holstein. The subsequent maintenance of the hedges and the “cutting back to the trunk”[12] is the landowner’s responsibility.

Further information: https://www.ecodots.de/leistungen/knicks

[12] This refers to the radical cutting back of shoots.

Figure 20: Erosion control strip and partial mowing at the edge of a field. ©WWF Frank Gottwald.

3.3.6 Riparian and buffer strips in grassland

Throughout Germany, along bodies of water, lake areas

Description of measure

These are strips of natural vegetation located at the edges of grassland areas that are extensively managed without the application of pesticides or fertilizers. They serve as important ecological barriers, established alongside water bodies and natural features such as forest edges. (Riparian) buffer strips are created either through natural regeneration or by sowing regional wild plant mixtures, and they must meet a minimum width of 3 meters according to the GAEC 4 standard. However, many federal states enforce stricter requirements, with average widths often specified between 5 and 10 meters (DVL, 2021a). These strips provide protection against the runoff of nutrients and pollutants into adjacent ecosystems, reduce erosion, and support the establishment of riparian plants and aquatic-dependent animal species. Regular maintenance of these strips involves adjusted mowing cycles and the removal of woody vegetation in riparian zones.

Figure 21: Unmown buffer strip along drainage channel. ©WWF/ Frank Gottwald.

Advantages for farmers

Riparian and buffer strips can be integrated with existing for fertilization and pesticide application, creating synergies and simplifying management. Additionally, they can serve as habitats for beneficial organisms.

Timeframe for impact

[short term]

Impact

Water balance	Riparian and buffer strips increase surface roughness, which slows surface runoff and slightly improves infiltration due to the greater species and root diversity of grasses and wild plants.
Water quality	This measure significantly reduces the use of pesticides in the area, thanks to a variety of regulations, and minimizes the input of fine sediments and nutrients into adjacent water bodies.
Biodiversity	Riparian buffer strips contribute to the connectivity of habitats and create migration corridors for amphibians, reptiles, and insects (DVL, 2021a). They also provide habitats for a wide range of plants and insects.
Other	Partial shading of water bodies helps mitigate water temperature increases, serving as an adaptation measure to climate change. Additionally, by maintaining ground cover, this measure helps reduce the risk of flooding during high water events.

Restrictions from an agricultural perspective

- Loss of productive grassland area
- Temporary management restrictions, such as limitations on cutting times, reduce forage quality

Implementation and cost estimate

This calculation considers the establishment of a field hedgerow (100 meters long and 5 meters wide per hectare) on grassland. In addition to the establishment costs for planting materials and initial maintenance, there are additional costs for pruning the hedgerow (in this example, every 10 years). The loss of grassland yield is also factored in but represents only a very small portion of the total area considered (500 m² per hectare). Over a 20-year period, the total costs amount to approximately €8,000.00 per hectare of total area (equivalent to 500 m² of hedgerow), which translates to roughly €400.00 per hectare annually.

Further information

In 2013, the German Federal Environment Agency (UBA) published a study examining the potential use of (riparian) buffer strips as short-rotation coppices (SRC) or agroforestry systems. According to the study, SRC buffer strips could not only enhance water protection but also contribute to agricultural value creation. More information is available here: https://www.umweltbundesamt.de/publikationen/gewaesserrandstreifen-als-kurzumtriebsplantagen

3.3.7 Conversion of arable land to grassland

Throughout Germany, North German Plain – East and West

Description of measure

Grassland includes both fertilized and unfertilized (hay) meadows and pastures, which serve purposes such as forage production, biomass generation, and bedding material, and are subject to legally defined minimum utilization periods (BfN, 2014). Moreover, grassland is among the most biodiverse habitats in Germany (Gottwald & Stein-Bachinger, 2016). The primary vegetation in grasslands consists of grasses or other non-woody plants, either naturally occurring or sown. When selecting seed mixtures, the intended use should be considered, and regional seeds should be used whenever possible, as they are adapted to local soil conditions and climate. This can ensure optimal establishment and long-term sustainability of the turf. Grassland, with its rooted soils and permanent ground cover, provides excellent conditions for water absorption and retention during temporary flooding (Beisecker et al., 2023). The rooted plant cover reduces surface water runoff, improves soil infiltration, and minimizes soil erosion. Proper maintenance of young grassland after sowing is crucial to prevent strong competition from weeds and to ensure the successful establishment of the turf. This may include watering or light fertilization if necessary. Established grassland requires regular management, such as appropriate grazing schedules and overseeding to fill gaps, to maintain turf vitality and realize the full ecological benefits of grassland areas.

Figure 22: Slope at risk of erosion converted to grassland. ©WWF/ Frank Gottwald

Benefits for farmers

In Natura 2000 areas and nature conservation areas, the measure is eligible for funding. To maximize the use of large areas and diversify income, certain grassland areas can be partially combined with photovoltaic installations and sheep grazing or other subsidized measures, such as small water bodies.

> *"Rewarding extensively used grassland is key for us. A classic example: we receive a premium of €240 per hectare for four indicator species. That's a lot of money for us and also recognition for our work.“ – David Henke, Uckermark Farmer*

Timeframe for impact:
[medium to long term]
Impact

Water balance	The measure enhances water retention in the landscape and significantly reduces surface runoff during heavy rainfall. However, grassland, due to its permanent vegetation cover, experiences higher evaporation rates compared to arable land (Beisecker et al., 2023).
Water quality	Grassland protects the water quality of adjacent water bodies by trapping sediments and assimilating nutrients. The filtering effect of its permanent vegetation also preserves groundwater quality, significantly contributing to the reduction of phosphorus and nitrate pollution. Additionally, soil erosion is substantially lower compared to arable land.
Biodiversity	Extensively managed pastures and meadows are biodiversity hotspots, providing habitats and breeding opportunities for amphibians, insects, birds, and wild herbs. They also positively influence the spatial and functional connectivity of habitats.
Other	Grasslands store significantly more carbon than arable land (Jones & Donnelly, 2004). This not only makes them a critical contributor to climate protection but also provides potential for temporary water storage during flooding events.

Restrictions from an agricultural perspective

- Land use competition
- Loss of yield
- Decrease in value due to loss of arable land status
- Special requirements for areas designated as Natura 2000 habitat types
- Compliance with agricultural subsidy regulations

Implementation and costs

For the permanent conversion of arable land to grassland, the significantly lower gross margins of grassland compared to arable land, as well as the reduction in market value due to the loss of arable status, must be taken into account. This issue creates high conflict potential and, consequently, low acceptance of the measure. If implementation is pursued, a medium compensation amount of approximately €23,000.00 per hectare is recommended, depending on the location, in the form of compensation payments, direct payments, or subsidies. Due to the high conflict potential of permanently converting arable land to grassland, a temporary sowing of forage grass for five years can be an alternative.

In this scenario, the arable status of the land is maintained, avoiding any reduction in market value. Compensation would only cover the lower gross margins from forage grass cultivation compared to "traditional" arable crops like rapeseed, wheat, or barley. The difference amounts to approximately €670.00 per hectare annually, totaling €3,350.00 per hectare over five years. The availability of regional markets for the harvested material (silage or hay) is a prerequisite for the acceptance of both measures (permanent grassland or agricultural grass).

Further information

In its overview of agri-environmental measures, the engineering office Schnittstelle Boden in Hesse collects valuable tips on measures that contribute to groundwater and surface protection and to reducing the eutrophication of surface waters. It also includes funding procedures and associated requirements for the conversion of arable land to grassland, grassland extensification or animal-friendly mowing.

Further information can be found at: https://www.schnittstelle-boden-wrrl-hessen.de/

Figure 23: Species-rich grassland with pasture. ©IFÖL/ Johanna Krähling.

3.3.8 Vegetated drainage swale

From the Central German Loess Börde to the Alpine Foreland, slopes at risk of erosion

Description of measure

To channel surface water across agricultural land without causing soil erosion, vegetated drainage swales can be established. These are broad, shallow, and typically saucer-shaped channels where excess rain or irrigation water flows. According to *Keyline Design principles*, the site should utilize a natural, pre-existing drainage path shaped by the terrain. The dimensions depend on the size of the catchment area or the known runoff volume at the location. In these elongated swales, a strip of grassland is either sown or left to natural vegetation. This slows the water flow across the surface, allowing grasses and stems to intercept and facilitate direct infiltration. This helps reduce or delay peak runoff events (Botschek et al., 2015). The root systems and surface cover prevent the rapid transport of loose soil particles by water, acting as a sediment filter during heavy rainfall.

- Keyline Design *(Schlüssellinienkultur)* refers to the strategic planting and land management along contour lines to optimize water retention, distribution, and storage of rainwater. Using digital terrain models and remote sensing data, cultivation and planting patterns (the 'keylines') are designed to guide water along the land's contours and reduce slope lengths (DVL, 2021a).

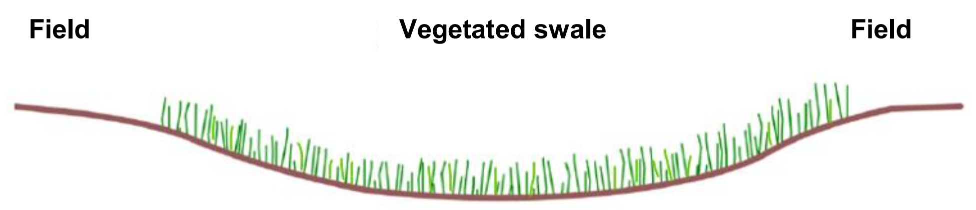

Figure 24: Schematic sketch of a vegetated swale © Own illustration, based on bodenstaendig.eu

Benefits for farmers

Vegetated drainage swales prevent the water-driven erosion of topsoil, thereby contributing to the preservation of soil fertility. They help avoid economic losses in arable land caused by siltation or gully erosion.

"If there's another research project on the topic of Keyline Design and they're looking for suitable areas, that's definitely something I would be interested in trying out." – David Henke, Brandenburg Farmer

Timeframe for impact:
[very short term]

Impact

Water balance	The increased surface roughness delays and spreads surface runoff, positively affecting soil water retention. The higher infiltration rate also improves groundwater recharge (Bäuml, 2020). However, the larger extent of moist, vegetated surfaces can slightly increase evaporation.
Water quality	Vegetating drainage channels significantly reduce the runoff of fertilizers and pesticide particles, thus improving the water quality of nearby surface waters (DVL, 2021a; Fiener & Auerswald, 2003). By trapping eroded soil particles around plant roots, the measure also prevents water turbidity.
Biodiversity	This approach positively impacts local biodiversity and species richness by connecting corridors and habitats for insects and small organisms.
Other	The reduced runoff velocity contributes to flood protection. At the edges of tree rows in agroforestry systems, vegetated mounds can serve as water retention areas, further enhancing water-holding synergies.

Restrictions from an agricultural perspective

- Partly difficult integration into land management; dividing agricultural land at unfavorable angles can create residual areas that are challenging to manage with machinery.
- Significant effort required for precise measurements following the Keyline Design principles.
- Potential distance requirements for fertilization and pesticide application.

Implementation and cost estimate

For establishing vegetated drainage swales in the form of grass strips within natural, terrain-defined drainage channels, the loss of market value due to the removal of arable status is used as a basis for calculation. Unlike buffer strips and converted grassland, no agricultural use of the vegetation is intended, so the compensation for permanent establishment is slightly higher at approximately €28,900.00 per hectare of swale area. These costs are primarily due to the loss of agriculturally usable land. The establishment of vegetated swales itself is relatively inexpensive: targeted vegetation establishment costs around €300.00 per hectare. Depending on the known runoff volume, a grass strip is sown into an existing terrain depression. The swale should be designed to ensure a broad and even water flow while being positioned in a way that does not interfere with the management of the overall area (Bäuml, 2020). To maintain a dense grass cover, regular mowing is recommended. However, after the grass cover is well-established, minimal maintenance is required over extended periods (Botschek et al., 2015).

Further information

The practice platform for soil and water protection, "**boden:ständig**," offers planning and implementation assistance and includes a collection of successful projects across southern Germany, where vegetated drainage swales have been established.

For further information and inspiration, please visit: www.boden-staendig.eu/.

3.3.9 Small retention areas and small water bodies in fields

North German Plain – East and West, Central German Uplands, loamy soil layers

Description of measure

The measure involves the development, restoration, and maintenance of small water retention areas or wet depressions along ditches, tree strips, and natural small water bodies such as ponds, pools, or near-natural lakes. These water bodies contribute to stabilizing the water balance by capturing water during heavy rainfall and allowing it to infiltrate slowly (Botschek et al., 2015). Additionally, they provide cooling effects on hot days through increased evaporation, benefiting surrounding crops (UBA, 2022). For grazed areas, parts of the shorelines should be fenced off to preserve vegetation and protect habitats for specialized species like dragonflies and the fire-bellied toad. In areas used for farming, it is essential to establish protective strips around the water bodies and avoid plowing near them (Gottwald & Stein-Bachinger, 2016). In dry years, plowing dried-out shallow water bodies can be beneficial to prevent silting and encourage the creation of open shallow water zones (DVL, 2018). Ponds, as the smallest type of standing water, may dry out several times a year. Beyond their ecological advantages, these water bodies serve as distinctive landscape features, offering aesthetic and tourist appeal.

Figure 25: Small water body on pasture. ©Ecologic Institute/ Ida Meyenberg.

Benefits for farmers

Enhanced water retention can reduce water stress for surrounding crops during dry periods and help stabilize yields. In many federal states, small water bodies below a certain square meter threshold qualify as structural and landscape elements, making them eligible for subsidies. Additionally, the construction work for these features is often covered by funding programs.

"Two small bodies of water on our land have now been renaturalized by the WWF, one on arable land and one on grassland. The success of these measures is clearly evident. We take aerial photos, [...] and you can clearly see that there is still water there. Previously, there was no water left—the water was gone." – Anne Kettner, Crane Conservation Germany

Timeframe for impact:
[short term]
Impact

Water balance	The extension of runoff paths (e.g., through infiltration) and the delay of runoff (via small retention areas or similar structures) influence the shape of the runoff hydrograph in water bodies. This can be intentionally utilized to reduce or delay peak runoff during heavy rainfall events. In general, retaining runoff (as surface water or in infiltration zones) can increase evaporation, which also impacts the runoff volume (Botschek et al., 2015). Small retention areas promote infiltration and can support groundwater recharge, contributing to the long-term stability of the water balance.
Water quality	Intercepting and capturing surface runoff on fields can prevent nutrient-rich sediments from entering nearby watercourses. This reduces phosphate pollution in receiving waters, as small water bodies act as sediment traps. However, nutrient inputs into the water body itself may affect its quality.
Biodiversity	Ponds and small wetlands are among the most biodiverse ecosystems in the region. These water bodies provide habitats for almost all local amphibian species and support over 2,000 insect species, along with snails and worms (Gottwald & Stein-Bachinger, 2016; LBV, n.d.). The creation of such small water bodies establishes new habitats, playing a critical role in aquatic biodiversity. Acting as island-like connections between distant habitats, they facilitate recolonization and migration (IGB, 2022).
Other	Synergies are particularly effective when small retention areas are combined with extensive grazing systems and the creation and management of wet and marshy grasslands. Where feasible, multiple water bodies with varying depths and structures should be established in close proximity to each other. **Tip:** Watercourse excavations can be combined with the creation of new hedgerows (Knicks). The excavated soil can be used to build the hedge wall.

Restrictions from an agricultural perspective

- Additional management or distance requirements for surrounding agricultural land.
- Challenges in cultivating adjacent agricultural areas due to unfavorable field geometry.
- Loss of productive arable land or high-yield grassland.

Implementation and cost estimate

The creation of small retention areas and water bodies in agricultural landscapes is often not a measure that can be implemented by farms alone. Instead, in some cases it requires collaboration with the local municipality, water management authorities, and potentially consulting services for implementation. In addition to the costs of land loss (as outlined in section 3.3.8), expenses for necessary earthworks, initial planting, and other tasks must be considered. As such, no precise cost estimate can be provided here. However, if dried-out areas are to be plowed, costs of approximately €140.00 per hectare can be expected.

The design and shaping of individual water bodies should align with the target species that are already regionally present. Attention should be given to creating varied shoreline profiles and different water depths. Maintenance work on the water bodies should take place between October and January, while buffer and edge strips should be mowed starting in September, with the clippings removed if possible.

Further information

The German Association for Landscape Conservation (Deutscher Verband für Landschaftspflege, DVL) has published useful tips on funding opportunities for creating small water bodies as part of its nature conservation advisory program in Schleswig-Holstein (DVL, 2018). Comprehensive information on the maintenance of such water bodies can also be found from the German Environment Agency (UBA) or NABU.

In the joint project *"Connected Diversity on the Treasure Coast"*, WWF Germany is working on restoring up to eight small water body complexes, thereby enhancing the diversity of species and habitats in agricultural landscapes.

Figure 26: Wetland patch at the edge of a field. ©WWF/ Frank Gottwald.

Biodiversity, Groundwater recharge

3.3.10 Creation and management of marshy and wet grassland

North German Plain – East and West, Upper Rhine Rift Valley, Alpine Foreland

Agricultural areas along watercourses, located in depressions

Description of measure

Species-rich wet and marshy grasslands along flowing waters, in spring-fed areas, and in peat-influenced depressions and slopes form valuable ecosystems. These habitats include meadows and pastures on moderately to well-nutrient-supplied sites; wet to intermittently wet sites, ranging from expansive areas to small-scale patches. Characterized by groundwater, standing water, or spring water, as well as occasional flooding, they typically have a water table 10 to 30 cm below the soil surface. Various types, such as Molinia meadows (purple moor grass) and tall sedge swamps, provide specialized habitats for numerous plant and animal species (NLWKN, 2011). In floodplains, they form complexes with flowing and standing water bodies as well as floodplain forests. These areas require extensive grazing adapted to the meadow type, using animals such as water buffalo, sheep, cattle, or horses. High residual vegetation from selective grazing, where ungrazed patches cover more than 50% of the area by autumn, is common in continuous grazing systems and often desirable from a faunal perspective. Restoration typically involves technical and structural measures, such as modifying drainage systems or installing water retention structures, to achieve the ecologically required target groundwater level. Unlike permanently waterlogged peatlands, wet meadow restoration allows for more flexible management, reducing conflict potential while significantly contributing to groundwater recharge (Beisecker et al., 2023).

Figure 27: Wet grassland with high water levels. ©WWF/ Alexander Paul Brandes.

"There's already a farmer managing another lake there, and it works quite well with old breeds. Allgäu Brown Cattle and a few other breeds handle this moisture well. In winter, when the water level is very high, the animals move to higher areas, and in summer, they graze back the reeds that spread there." – Anne Kettner, Crane Conservation Germany

Benefits for farmers

With a well-integrated land-use concept, income can be diversified through nature conservation services (e.g., extensive grazing), and the areas can be utilized for tourism and recreational purposes. Additionally, purple moor grass is a valuable source of bedding material, making it popular for use in livestock stalls.

Timeframe for impact:
[medium term]
Impact

Water balance	By eliminating drainage and enhancing soil water storage across the area, this measure has a particularly positive effect on the slow process of groundwater recharge. Initially, new wet grassland provides greater soil water availability. However, in dry years, evaporation rates over wet grasslands are higher, which can result in a variable impact on the overall landscape water balance.
Water quality	The management practices, often involving the avoidance of pesticides and insecticides, have a highly beneficial impact on water protection and contribute to reducing sources of pollution.
Biodiversity	Species-rich wet and marsh grasslands are habitats for highly endangered plant species. In water-rich years, they also serve as important spawning habitats for certain amphibians and the grass snake. Additionally, they are key breeding grounds for meadow birds, such as the lapwing (*Vanellus vanellus*) (BfN, 2015). Through the targeted integration of small habitats along flowing waters and their associated riparian vegetation, such as riparian woodlands, wet meadows can foster valuable habitat networks. *Molinia* meadows, which typically require (intermittently) wet, nutrient-poor sites, are recognized as an independent habitat type under the EU Habitats Directive (6410).
Other	As part of near-natural river floodplains, wet and marsh meadows play an important role in flood protection. Significant synergy effects can be achieved by adding small water bodies and ponds, which can further enhance biodiversity.

Restrictions from an agricultural perspective

- Low forage value for vegetation
- Requires tailored grazing management
- Timing and intensity of use often lead to conflicts with meadow bird conservation goals

Implementation and cost estimate

This measure may require technical and structural changes (e.g., removal of drainage systems, construction of dams), which makes implementation by agricultural operations alone impractical. Additionally, the scale of work depends heavily on the initial conditions, making it difficult to provide a cost estimate for establishing wet grasslands. For maintenance, regular mowing with the removal of cuttings incurs costs of approximately €550.00 per hectare per cut.

The wetter the site, the more likely it is that it can only be used as a mowing meadow, possibly with grazing in late summer. Most areas should be mowed twice a year due to their nutrient levels, with the cuttings removed. Mowing should ideally proceed from the center outward or in overlapping sections from one side to the other.

Nutrient-poor wet meadows, such as those with marsh marigolds, typically require only one cut per year. Utilization should be small-scale and staggered over time to ensure a continuous supply of flowering plants.

Further information

The DVL brochure "*Moor Climate Farmers: The Future of Agriculture in Peatlands*" (DVL 2021) showcases farmers who are successfully managing wet or waterlogged soils as exemplary case studies. The brochure also outlines opportunities for training and further education for moor climate farmers.

The rewetting of grasslands is one of several measures supported by the WWF office in Stralsund through the pilot project *Krautsander Naturrind für Artenvielfalt* (Krautsand Natural Cattle for Biodiversity). This project simultaneously promotes local biodiversity and helps establish new market opportunities for farmers in the region.

Figure 28: Utilization of Wet and Marsh Grasslands with Adapted Cattle Breeds. ©Pixabay/ Adina Voicu.

Legal framework for waterlogging grassland

The modification of drainage systems and the installation of water retention structures may constitute regulated uses of water bodies requiring authorization. Such activities must be approved by the competent water authority under § 8 of the Federal Water Act (WHG). For more extensive measures affecting the water balance of neighboring properties, these may be classified as watercourse modifications under § 68 WHG, necessitating a comprehensive planning approval process. Additionally, the measures may impact the habitats of protected species, such as the skylark or European hamster. In such cases, a special exemption permit under § 45 of the Federal Nature Conservation Act (BNatSchG) may need to be obtained. For larger-scale rewetting projects on grasslands, it is advisable to familiarize oneself with the relevant legal requirements early in the planning process.

4 Practical Examples of the Implementation of Measures

For a tangible presentation of the measures outlined in Chapter 3.3 for improving the landscape water balance, it is essential to take a look at local practice. In interviews with farmers, experiences, recommendations and findings were collected, which were used to develop practical scenarios that show how sustainable water management can be implemented in agriculture[13]. The toolbox of possible measures is diverse and also exceeds the ten measures that are examined in more detail in this handbook.

The practical examples presented here are abstracted. They are based on experiences from interviews and provide a practical insight. The following questions are addressed:

- Which measures are particularly suitable in combination and under which local conditions?
- What unexpected hurdles or successes could be achieved through the interaction of measures for the water balance of farms and beyond?

The following chapters first outline the prevailing conditions on the ground and then describe the corresponding implementation of measures. In addition, they are categorized according to the natural spatial division outlined in Chapter 3.1.

4.1 Farm A – Extensive Livestock

Extensive livestock farming in Brandenburg with temporary grassland on arable land with undersown crops

Location: northern Uckermark (BRB)	Natural area: Brandenburg young moraine land (Natural area 3)
Precipitation/a: 500 mm	Farm type: organic mixed farm (cattle)
Operating form: family-owned farm	Farm size: >2.000 ha
Soil: Regosol	

Brief description: A large family farm with organic farming is located in a region surrounded by many lakes, little rainfall and low field value. The land is part of a biosphere reserve. The farm operates mainly on owned land. The farm is located in the North German Lowlands East and has a continental climate. The farm cultivates on medium-textured, partly shallow loamy, loamy-sandy and sandy soils of boulder marl or boulder clay and plateau sands as well as sandy-gravelly formations of the terminal moraines and dissected areas, mainly in the area of the Vistula glaciation (soil atlas).

Measures: *Four years of alfalfa-clover grass in the crop rotation with arable land used temporarily as permanent grassland · Catch crop cultivation and undersowing crops · Experimental mob-grazing[14] · Use of Keyline Design[15] · Reduced soil compaction*

[13] The interviews focused on the North-East Germany region due to the existing network in this region.
[14] Mob grazing is part of a grazing strategy for drylands and adapted plant populations. It is a type of optimized, intensive strip-grazing within a paddock and is based on wild animal herds of the savannah.
[15] Planting of an area or landscape in a line adapted to the terrain. The design method is primarily aimed at optimizing water retention and improving the distribution and storage of rainwater.

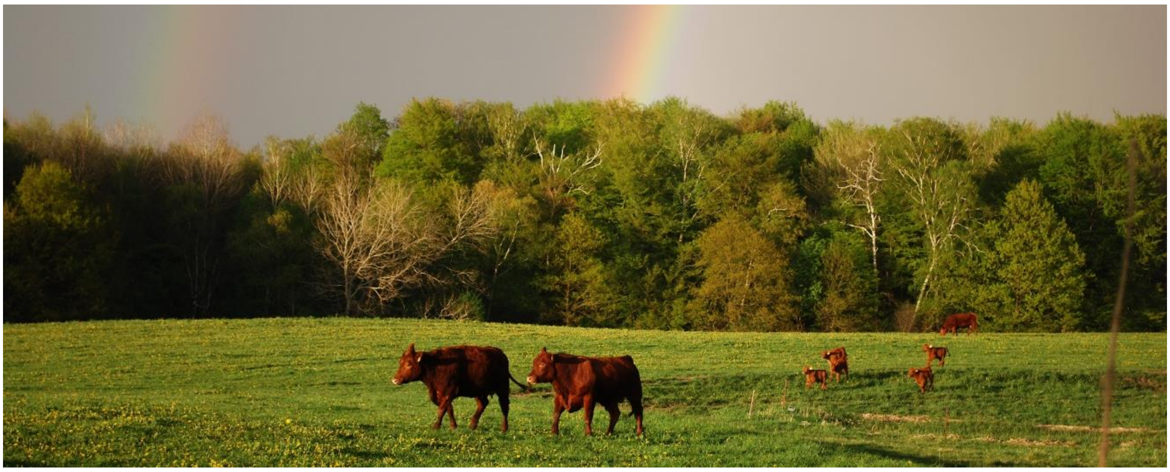

Figure 29: Extensive grassland. ©WWF/ Frank Gottwald

Legumes are established in the already **enhanced crop rotation** as an adaptive measure due to low rainfall and sandy soils. Legumes are used beyond the usual two years in the crop rotation. The nutrient effects decline significantly after two years, which is why they are usually discontinued after that. As the deep-rooted structures and the use as pasture fodder are advantageous for the farm in addition to the nitrogen fixation in the soil, it is kept longer in the crop rotation in this case. The regrowth of the pasture serves as an indicator for a functioning water balance. The crop rotation is adapted to the conditions of the soil and the weather. The farm uses its possibilities in farm management to counteract the increasing extreme weather events.

Catch crops and undersown crops are an important part of this. These are cultivated to ensure that the soil is covered as permanently as possible. This prevents the valuable soil from being eroded by wind or water. It also increases the root growth of the soil and resilience to periods of drought thanks to the pores that deep-rooted catch crops create. In addition, the cover crop or catch crop can be used as a feed stock for internal farm cycles. The rest is mulched and promotes humus formation in the soil. **Vehicular traffic should be kept to a minimum** to avoid soil compaction. Twin tires should be used for this purpose. Denser soils have less water infiltration into the topsoil due to the lower water storage capacity of the soil pores. Avoiding harrowing or additional tillage also protects the soil structure and thus promotes the humus development as well.

Extensive cattle farming is part of the crop rotation on this example farm. After the market crops, the arable land is used as temporary grassland for four years with grass mixtures with alfalfa, which also ensures the forage stocks in dry periods. The frequent rotation of the subareas keeps trampling and browsing pressure on the soil and grasses to a minimum and also enables the animals to be kept outdoors all year round in an environmentally friendly manner. The flexibility provided by the availability of many areas on the farm is an advantage here.

As part of the temporary conversion of arable land into pastureland, innovative methods such as **mob grazing** are being tested **in collaboration with research projects** to build on and advance latest scientific findings. Mob grazing, for example, has positive effects on the regrowth of grassland. The infiltration capacity of grassland is reduced if the turf is damaged or the soil is compacted, which is often the reason for intensive grazing. Photosynthesis is important for soil organisms, which is why appropriate pasture management ("strip-grazing") prevents damage[16]. In another project at the same location, the advantages of **Keyline Design** are being tested. Modern surveying techniques, remote sensing and hydrological models are being used

[16] Deutsche Vereinigung für Wasser Wirtschaft, Abwasser und Abfall e.V. (ed.) (2015): Wasserrückhalt in der Fläche durch Maßnahmen in der Landwirtschaft- Bewertung und Folgerungen für die Praxis

to analyze how water moves across an agricultural area. The aim is to identify so-called "keylines", which, like contour lines, usually run horizontally to the natural slope gradient.[17]

The **increased costs** resulting from the additional work and possibly lower income from climate-adapted measures are a challenge for the farm, which can only be covered by a combination of subsidies for organic farming and subsidies within the framework of nature conservation and a functioning sales market for organic meat products. There is often a lack of financial incentive to implement measures that exceed the minimum standards for qualifying for subsidies in a commercially viable way. The backing of a broad-based family business with a history and corresponding size under its own ownership creates additional flexibility to compensate for lower yields and makes it possible to cushion the risk of openness to innovation. In addition, the responsibility for the business, the region and the ecological environment that has grown over generations brings a higher degree of involvement in transformation processes with a longer time horizon and a more distant goal compared to short-term profit maximization on changing leased land.

4.2 Farm B – Conventional Mixed Farm

Conventional mixed farm in south-western Saxony-Anhalt with direct sowing (no-tillage), reduced tillage and minimal vehicular traffic

Location: Northern Harz (ST)	Natural area: Central German loess plains
Precipitation/a: 400–450 mm	Farm type: conventional mixed farm
Operating form: agricultural cooperative on leased land	Farm size: 100 ha
Soil: Alluvial soil	

Brief description: A small agricultural cooperative with arable farming and animal husbandry on predominantly leased land in the northern foothills of the Harz Mountains with very heterogeneous soils that vary between 20 cm and 100 cm of topsoil. Both high quality loess soils and stony and sandy soils with a low arable value can be found on the farm. The region between Harz and Dessau is one of the regions in Germany with the lowest rainfall.

Measures: *Direct sowing · Reduced tillage · Broad crop rotation with catch crops · Site-adapted load input*

Figure 30: Stubble left standing after harvest. ©WWF/ Frank Gottwald.

[17] https://www.oekolandbau.de/landwirtschaft/umwelt/klima/keyline-design-landwirtschaft-optimieren-mit-intelligenter-wasserfuehrung/

Direct sowing (no-tillage) makes it possible to avoid plowing up the soil. After the harvest, the stubble remains in the field over wintertime. For sowing the seeds are placed directly into a gap in the soil. The premise is to minimize soil tillage. Successful application requires an **adapted crop rotation** including catch crops for year-round soil cover. In this way, tillage, chemical-synthetic plant protection measures and fertilization can be reduced. Moving the soil as little as possible has the advantage that the mulch layer remains intact. This regulates the soil temperature and minimizes evaporation. This can lead to faster and better field emergence after sowing. **Reduced tillage** is particularly suitable on lighter soils, as water availability is the critical site factor for an optimized harvest. Higher proportion of organic material in the soil can absorb larger quantities of water and store it over a longer period. This means that the soil is better equipped to cope with heavy rainfall events and droughts that have become more frequent in recent years. To assess the condition of the soils and the effect of the measures, soil samples are taken regularly or sometimes just the temperature and moisture are checked.

For direct sowing (no-tillage) in general, herbicides are needed to cope with the weeds. This is one of the reasons why the farm cannot convert to organic farming.[18] Since no-tillage farming has a clear focus on protecting the natural resources of water and soils, the farm considers itself as a **hybrid farm**, i.e. a combination of conventional and organic measures that utilizes the advantages of both systems.

The transition to no-till technology and the associated costs are a hurdle, despite the advantages. For example, the machines used for tillage, such as plows, harrows or cultivators, are exposed to considerable forces when breaking up the soil structure, which not only lead to high energy and thus diesel consumption, but also causes material wear and negatively affects the durability of the equipment.

4.3 Farm C – Organic Farming

Farm on the Baltic Sea coast in Schleswig-Holstein converted to organic farming with adapted crop rotation on arable land with historic hedgrows and a market garden with a rainwater retention basin.

Location: Western Baltic Sea (SH)	Natural area: North German Lake District (Natural area 3)
Precipitation/a: >800 mm	Farm type: organic mixed farm + horticulture
Operating form: family farm with the majority of land owned by the farmer	Farm size: <150 ha
Soil: Pseudogley-luvisol	

Brief description: An organic farm with a market garden center supplied through a rainwater retention basin, without irrigation on the fields in a region with a lot of clay in the soils and high field values. Medium to deep, loamy-sandy to loamy-silty, partly stony, brown soils with clay-rich subsoil (haplic luvisol and podzoluvisols) and mostly calcareous subsoil; often temporary waterlogging in the topsoil (pseudogley-luvisol soil to pseudogley) from boulder clay over shale marl, usually with loamy-sandy topsoil (soil atlas). Some of the land is leased, but the majority is owned land.

Measures: *Creation of small retention areas · Adapted crop rotation · Reduced tillage · Site-adapted vehicular traffic · Hedgerows*

[18] There are only a few exceptions, where organic farms can handle direct sowing (no-tillage), due to the need for herbicide usage in most cases.

Figure 31: Plot boundaries with vegetation. ©WWF/ Frank Gottwald.

Due to the hedgerows that historically developed in Schleswig-Holstein, the fields on the farm are divided into many **small areas**, mainly between arable land and grassland. The hedgerows protect against soil erosion and promote a milder microclimate for the adjoining horticultural area of the farm. This promotes a good balance of parasites and beneficial insects, especially in combination with flowering areas. The farm also has meadow orchards, which provide protection against wind erosion and protect the rainwater retention basin. Agroforestry on the arable land would be a possible future development, as the farm's infrastructure for fruit trees is already in place.

As part of the **conversion to organic farming**, the farm had to phase out synthetic chemical pesticide and synthetic fertilizer use while the **crop rotation was adjusted**. The use of **catch crops and crop mixtures** such as spring barley with peas were established to increase the adaptability of the soil to weather conditions and nutrient requirements. The seeds for the crop mixture of barley and pea are produced on the farm. Mixed crop cultivation has many positive ecological effects. Mixed crops provide habitats and food sources for a greater variety of insects, which in turn increases the food supply for other animal species. Mixed crops also improve stability and harvest. Nutrients, water and light are used more efficiently, so that pests and diseases occur less frequently and yields actually increase. Thanks to the denser ground cover, fewer weeds grow, meaning that weed control measures need to be applied less frequently. This benefits ground-nesting birds and field dwellers such as skylarks, lapwings, corn buntings, pheasants and brown hares. Sowing is then carried out with the support of the skimmer plough, which is used to cultivate the soil to a shallow depth of 8–16 cm.

As part of a **nature conservation** program, larger fields are turned into smaller ones so that more field boundaries are created. The program is attractively remunerated. The effect is positive because it is used across the board and creates many meters of field boundary. Thanks to modern **technology with GPS control**, the **small size** of the areas can be handeld. Instead of ten paddocks there are almost a hundred, which are organized with a digital field index. Only the management of the land is more complex.

Technical measures such as tire pressure control systems and the use of the same lanes when spreading liquid manure to **reduce soil compaction** are used to counteract the vehicular traffic that occur on the arable land. The noticeable changes in the temporal distribution of precipitation and more frequent spring droughts can be better buffered due to the very good geological conditions of the loamy soils but remain a challenge. The water required for horticulture is obtained from **rainwater retention basins**. These were originally installed as buffer basins as part of a requirement to protect the public sewage systems. The basin is normally filled half to three-quarters. During heavy rainfall events, the level fluctuates upwards. This additional water is then slowly released into the public drainage system with a delay. In drier periods, the water is removed from the basin and used for gardening. In cases of frequent heavy rainfall, where the soil can only absorb limited amounts of water, the retention basins have the ability to absorb and temporarily store excess surface water. In this way, they help to protect low-lying areas from flooding. The basin never falls completely dry, as it is also integrated into a biotope area. Regionals seeds are sown around the basin with extensive cultivation. The body of water is designed as a biotope area: a meadow orchard and over 1000 meters of hedgerows are part of it.

Financial support and market prices do not adequately reward more sustainable farming methods. Public relations work is used specifically to communicate the public benefits. Farm-gate sales and farm visits are used to show the region where the added value lies in environmentally friendly production, thereby improving customer loyalty and acceptance of higher prices.

4.4 Nature conservation association

Cooperative restoration projects of lake areas and peatlands in northern Mecklenburg-Western Pomerania with wet grassland and small retention areas with a focus on nature conservation projects in arable farming regions.

Location: Western Pomerania (MV)	Natural area: Mecklenburg-Western Pomerania coastal area (natural area 3)
Precipitation/a: 700 mm	Farm type: nature conservation association
Operating form: limited liability company with its own land	Farm size: <100 ha
Soil: Fen soil	

Brief description: A non-profit nature conservation company acquires land around a lake in order to carry out rewetting measures. The region is characterized by agricultural land with high field values, which is predominantly cultivated with intensive arable farming. The soils are groundwater fed, partly calcareous fen soils, mainly consisting of heavily decomposed, topogenic swamp forest, reed or radicellar peat or fen, often associated with mire gley, peaty mineral soils and gley (soil atlas).

Measures: *Conversion of arable land to grassland · Purchase of arable land for biodiversity projects · Creation of small retention areas · Restoration of small water bodies*

Figure 32: Small bodies of water surrounded by agricultural area, Günzer See. NABU Crane Center.

In response to a continuously dwindling water supply in the surrounding waters, a large-scale long-term project is planned to keep water in the region and to raise the water level. With a focus on nature conservation, the association therefore decided to seek alliances with local farmers in order to develop joint usage concepts and acquire funding from NGOs and support programs. The first **restoration of small lakes** have already shown visible success and, in direct comparison, aerial photographs show water in places where there had been none in recent years. The lake had already dried up several times in recent years. The area is located in a polder that is being drained. In this context, it is important that farmers still have access to the agricultural land around the lake for cultivation. These areas are used in particular for spreading liquid manure from livestock farming. So far, two small bodies of water have been restored, one arable and one grassland.

As the project aims to gain acceptance from the surrounding farms in the region for better water retention, the process is lengthy and requires intensive communication. One important finding is that the **acquisition of land** is key to implement land use changes and projects to improve the landscape water balance. This is **cost-intensive and also bureaucratically challenging** (see Chapter 5 for further details on the success factor of securing land). The reluctance of farms to accept temporary productivity losses or closures is a major hurdle. The official channels take time and in some cases, construction windows are set in months when excavators cannot enter the area due to the soil conditions.

The aim of the project is to gradually rewet the areas in the project region while keeping the land economically viable. This can be achieved through **paludiculture,** by grazing the area with cattle without the use of heavy mowing machines. Until now, they are working together with the surrounding farms to find a way of extending the use of the land for all parties. An organic farm grazes the already rewetted areas and has changed the focus of its breeding to animals that cope well with the wet soil conditions. This has resulted in a marketable compromise with nature conservation. The ecological gain for the common good is co-financed by public funds and associations.

Good public relations work and networking with local stakeholders and authorities is enormously helpful for implementation. This requires (municipal) political backing and supporters must be gained in order to jointly realize unconventional nature conservation projects. Many information events and discussions with other companies and landowners as well as stakeholders in the region supported this process. The fact that the nature conservation association has been active in the region for over 30 years helped to overcome prejudices against the project.

5 Success Factors

In the previous chapters, individual measures and practical examples for improving the landscape water balance were presented. In this chapter, relevant success factors and levers will be outlined. These approaches can be used to scale transformation processes.

Figure 33: Pasture feeding at the edge of the river bank. ©Pexels/ matthiaszomer.com.

Funding opportunities and incentives

The provision of funding opportunities through **funding guidelines, programs and subsidies** is a key success factor for the implementation of sustainable water retention measures. The DVL recommends additional incentives for farmers that go beyond minimum requirements. Such incentives could be reinforced by bonus programs and help to ensure long-term acceptance and implementation[19]. All levels must be taken into account, from the Common Agricultural Policy at EU level to federal climate protection measures and voluntary agri-environmental and climate measures to regional funding. Tailoring these measures to local geological and hydrological conditions is crucial. Funded projects such as the Fichtwaldmoor in southern Brandenburg[20] or the state funding in Hesse for regenerative agriculture[21], which focus specifically on measures that optimize the water balance in agricultural soils, are positive examples. However, financial support is often missing, and farms lack the financial incentive to go beyond minimum requirements – such as a minimum number of indicator species. Incentives for farms to implement measures that go beyond the minimum requirements would be helpful.

Nature conservation programmes offer farmers the opportunity to generate additional income through specific water retention measures. Such an approach promotes a willingness to cooperate and makes it possible to implement nature conservation measures that go beyond the

[19] See DVL brochure (2023)
[20] https://fib-ev.de/projekte/verbesserung-des-wasserrueckhalts-auf-landwirtschaftlichen-nutzflaechen-best-practice-beispiele-und-optionen-fuer-das-fichtwaldmoor-best-practice-fichtwaldmoor/
[21] https://llh.hessen.de/umwelt/boden-und-gewaesserschutz/projekt-wasserrueckhalt-im-boden-durch-regenerative-ackerbaumassnahmen-steigern/

minimum legal requirements. Cooperation with nature conservation associations or landscape conservation organizations can also contribute to the continuous optimization of measures.

Land purchase for long-term objectives

One factor for the feasibility of water retention measures is the purchasing of suitable areas. In particular, rewetting measures of drained soils under agricultural use, are often dependent on the long-term availability of land. The involvement of landowners and the willingness of government agencies to provide public land contribute to the continuity of such projects.

"The crucial issue is to get the land. The federal government made a big mistake in the past by selling its state-owned land"

– Environmental organization Mecklenburg Western Pomerania

Hybrid farming as a model for success

A promising approach to improving water retention is hybrid farming, which combines methods from organic and conventional agriculture. By combining proven practices, farms can increase their resilience to heavy rainfall events and periods of drought. In its brochure "Agriculture and water protection", the German Environmental Aid (German: Deutsche Umwelthilfe, DUH) emphasizes the potential of hybrid farming not only to improve soil water retention, but also to promote biodiversity (DUH, 2023). It should be particularly emphasized that a reduction in agrochemicals protects the soil structure and improves water infiltration. Direct sowing with a single herbicide application can be just as interesting for other farms. In turn, a significant reduction in the use of machinery and no-tillage can be established as more water-friendly measures. The strong separation between organic and conventional farms has its limits when it comes to funding positive environmental effects. Organic farming measures could be an interesting option for conventional farms with positive environmental effects if they are eligible for funding on an individual basis.

Figure 34: Small water bodies on grassland. ©WWF/ Frank Gottwald.

Collective measures and cooperation

When implementing water retention measures cooperation with other stakeholders such as water, agricultural and environmental associations are usually needed. The introduction of collective measures, such as the creation of joint water retention basins, requires the cooperation of several landowners and user interests. Collective approaches have advantages, as they increase the effectiveness of water retention measures, but at the same time require structured and long-term maintenance of common infrastructures. Especially in the case of public goods such as water or soil, the need to preserve them through collective action becomes clear. Since farmers are usually connected with a wide variety of actors in the region and the supply chain, this can be used for water retention measures. Local politics or environmental associations can provide the impetus for the networking, logistics and coordination of such networks.

Involving companies as part of collective measures could also be an option, particularly those from sectors that share responsibility, such as the food industry, chemical companies or retailers. Many companies have committed themselves to sustainability goals and want to reduce their ecological footprint. They also have an interest in securing water supplies in order to safeguard their supply chains in the long term. Partnerships between companies that jointly benefit from measures to preserve regional landscapes therefore make sense and are profitable. Companies can provide financial resources or offer subsidies to support land managers in implementing measures. They can also invest in research and development to research new methods and technologies to improve the water balance and develop them further with practical trials. Both sides can also benefit from public relations. Large retail companies can bring in financial support and infrastructure for larger campaigns while local companies can demonstrate their regional ties.

Advice and training

The involvement advisory services, such as those provided by the chambers of agriculture, is essential to provide farmers with targeted information on water quality improvements and efficient water management. It is crucial that agricultural advice is not just a one-off, but that it contributes to the continuous improvement of measures and techniques. The topic of water management should also be integrated into training at an early stage in order to establish the relevance of the water balance for agricultural operations from the beginning on. Especially during an apprenticeship there seems to be considerable potential dealing with this topic at an greater depth. Also in academia and academic education this should a greater focus, especially due to its cross-cutting nature for many disciplines.

Long-term review and adaptation of measures

Farmers should be willing to regularly review their measures and adapt them if necessary. Both in-house surveys and cooperation with research institutions and scientists can help with this. Through ongoing evaluation, improvements are continuously integrated and developments are recognized at an early stage. A willingness to innovate and adaptability are crucial in order to strengthen the soil water reservoir in the long term and meet the challenges of climate change. It is also essential for future-proof management on your own farm.

Research projects are also a good way to strengthen the exchange between different stakeholders. Innovative methods can be tested - such as mob grazing from profile A. On the other hand, valuable practical experience can be used and passed on to other farms. Farms are used to being adaptable due to the many variables that play a role in their operational success every year. This adaptability will also remain the key competence for a more sensitive approach to the water balance.

Figure 35: Water pipes in the field. ©Pixabay / Dimitris Vetsikas.

Raising awareness and public relations

"Do good and talk about it" also applies in the case of water retention. Despite sufficient evidence, the pace of progress is too slow. Greater awareness of the drastic nature of the impending water problems and the need for comprehensive and timely measures is therefore required at various points, taking into account the complicated local stakeholder situation. Firstly, in administration and politics, to set appropriate (financial) incentives. Secondly, a (greater) awareness of the problem in society to understand construction projects in the region or additional costs and to actively campaign for more climate-friendly and nature-based projects and become partners in the cause. Furthermore, companies that operate in the regions need a sense of responsibility in order to see themselves as part of the solution and actively support ecologically effective measures and projects with appropriate commitment and also take the initiative themselves. Finally, the agricultural businesses in the region themselves, should be able to positively demonstrate the implementation of measures to their neighbors and to communicate their own projects, to take their customers with them and to ensure the multiplication of the topic within their own network.

Figure 36: Water retention in the field. ©Pixabay / Ria.

To successfully scale up water retention measures in the agricultural sector, farmers must be supported with targeted advice, suitable financial incentives and stable cooperation structures. Securing land, cooperation across property boundaries and comprehensive training and advice are essential prerequisites for national implementation. In this way, water retention measures can contribute to securing water resources and strengthening the resilience of agricultural businesses not only locally, but also nationally.

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7 Annex

7.1 Complete table of measures with evaluation index (own visualization, based on Stein et al. 2024, Beisecker et al. 2023, Office International de l'Eau 2014, DVL 2021a, Gottwald & Stein-Bachinger 2016, Vieillard et al. 2020, LAWA 2022)

	Measure	Sector	Effectiveness – Water balance				Effectiveness – Water quality					Site-specific biodiversity		Potential for conflict
			Water supply in dry periods	Groundwater recharge	Water retention in the soil	Delay of runoff	Erosion protection	Water protection (physical/ chemical)	Reduction of nitrogen pollution	Reduction of the phosphorus load	Reduction of PPP usage	Biotope linkage	Biodiversity	
	Text		*++ = significant favourable effect; + = favourable effect; ?/0 = neutral or unknown effect; - = adverse effect*											
1	Afforestation of arable land, fallow land or grassland on slopes	Forestry	-	?/0	+	++	++	+	++	++	++	+	?/0	medium
2	Forest establishment on runoff-producing areas: Establishment of floodplain forest	Forestry	?/0	?/0	+	++	++	+	++	++	++	+	?/0	medium
3	Construction of sediment collection ponds	Forestry, agriculture	+	+	+	+	+	+	?/0	+	?/0	+	+	low
4	Creation of forest and shrub belts in agricultural landscapes	Forestry, agriculture	+	+	+	+	+	+	?/0	+	?/0	++	+	medium

	Measure	Sector	Effectiveness – Water balance				Effectiveness – Water quality					Site-specific biodiversity		Potential for conflict
			Water supply in dry periods	Groundwater recharge	Water retention in the soil	Delay of runoff	Erosion protection	Water protection (physical/ chemical)	Reduction of nitrogen pollution	Reduction of the phosphorus load	Reduction of PPP usage	Biotope linkage	Biodiversity	
	Text		*++ = significant favourable effect; + = favourable effect; ?/0 = neutral or unknown effect; - = adverse effect*											
5	Soil protection liming	Forestry, agriculture	+	+	+	+	+	+	?/0	?/0	?/0	?/0	++	low
6	Reactivation of basin catchment areas	Agriculture	++	++	+	++	++	++	?/0	?/0	?/0	++	++	low
7	Adapted selection of crops and crop rotation for better water retention and water quality	Agriculture	++	+	++	+	+	+	+	+	+	?/0	+	medium
8	Multi-crop cultivation (diversification)	Agriculture	?/0	++	+	++	++	+	?/0	?/0	?/0	+	++	medium
9	Reduced and conservative soil tillage	Agriculture	++	+	++	+	++	+	++	+	-	+	+	medium
10	Landscaping measures for structural improvement	Agriculture	++	+	+	++	++	+	?/0	+	?/0	+	+	high
11	Adapted sowing	Agriculture	+	+	++	+	++	+	++	+	?/0	?/0	+	medium
12	Construction of strip cultures along contours	Agriculture	+	+	+	++	++	+	?/0	+	?/0	?/0	++	high
13	Preservation or creation of meadows and pastures	Agriculture	?/0	+	+	+	++	+	?/0	+	?/0	?/0	+	low
14	Preservation of traditional terracing	Agriculture	++	++	+	++	++	+	?/0	+	?/0	?/0	+	low

	Measure	Sector	Effectiveness – Water balance				Effectiveness – Water quality					Site-specific biodiversity		Potential for conflict
			Water supply in dry periods	Groundwater recharge	Water retention in the soil	Delay of runoff	Erosion protection	Water protection (physical/ chemical)	Reduction of nitrogen pollution	Reduction of the phosphorus load	Reduction of PPP usage	Biotope linkage	Biodiversity	
	Text		*++ = significant favourable effect; + = favourable effect; ?/0 = neutral or unknown effect; - = adverse effect*											
15	Location-adapted load application	Agriculture	+	+	++	+	+	+	?/0	?/0	?/0	?/0	+	low
16	Erosion protection-oriented flow division through Keyline Design	Agriculture	+	++	+	+	++	+	?/0	+	?/0	+	+	medium
17	Creation of vegetated drainage swales	Agriculture	?/0	+	+	+	++	+	?/0	+	?/0	+	+	medium
18	Cultivate areas parallel to slopes	Agriculture	+	++	+	++	++	++	?/0	+	?/0	?/0	?/0	low
19	Plant agroforestry systems	Agriculture	++	+	++	++	++	++	+	+	?/0	++	++	medium
20	Optimize pasture management/ extensification of meadow and pasture management	Agriculture	?/0	+	+	?/0	?/0	+	+	?/0	?/0	?/0	+	low
21	Carry out loosening measures	Agriculture	+	++	+	+	++	+	-	?/0	?/0	?/0	+	medium
22	Select suitable crops for areas at risk of erosion	Agriculture	+	+	?/0	?/0	++	+	?/0	++	?/0	?/0	?/0	low
23	Creation of water retention basins	Agriculture	++	?/0	?/0	+	?/0	?/0	?/0	+	?/0	+	+	high
24	Adjustment of plot sizes	Agriculture	+	?/0	?/0	?/0	+	+	?/0	?/0	?/0	+	+	medium
25	Reduced livestock density	Agriculture	+	+	+	+	+	+	+	?/0	?/0	?/0	+	low

	Measure	Sector	Effectiveness – Water balance				Effectiveness – Water quality					Site-specific biodiversity		Potential for conflict
			Water supply in dry periods	Groundwater recharge	Water retention in the soil	Delay of runoff	Erosion protection	Water protection (physical/ chemical)	Reduction of nitrogen pollution	Reduction of the phosphorus load	Reduction of PPP usage	Biotope linkage	Biodiversity	
	Text		*++ = significant favourable effect; + = favourable effect; ?/0 = neutral or unknown effect; - = adverse effect*											
26	Creation of infiltration or percolation ditches	Agriculture	++	+	++	++	+	+	?/0	+	?/0	?/0	?/0	low
27	Establishment of erosion control strips and hedges on field margins	Agriculture	+	+	+	+	++	++	?/0	++	++	+	++	low
28	Winter greening/ intercropping/ soil greening (e.g. undersowing)	Agriculture	+	?/0	+	++	++	++	++	+	?/0	+	+	low
29	Temporary conversion of arable land to grassland	Agriculture	?/0	+	+	++	++	+	++	++	+	++	+	medium
30	Direct sowing	Agriculture	+	+	+	+	++	++	++	++	-	+	+	low
31	Agricultural consulting with a focus on site-adapted cultivation	Agriculture	?/0	+	+	+	++	++	++	++	++	?/0	?/0	low
32	Optimization of plant protection product (PPP) usage	Agriculture	?/0	?/0	?/0	?/0	?/0	++	?/0	?/0	++	?/0	++	low
33	Further recommendations for erosion control (water, wind)	Agriculture	?/0	?/0	+	+	++	+	?/0	++	?/0	?/0	?/0	low
34	Water retention in the field through small retention areas and small bodies of water	Agriculture, water	+	++	+	++	+	+	?/0	+	?/0	+	+	medium

	Measure	Sector	Effectiveness – Water balance				Effectiveness – Water quality					Site-specific biodiversity		Potential for conflict
			Water supply in dry periods	Groundwater recharge	Water retention in the soil	Delay of runoff	Erosion protection	Water protection (physical/ chemical)	Reduction of nitrogen pollution	Reduction of the phosphorus load	Reduction of PPP usage	Biotope linkage	Biodiversity	
	Text		*++ = significant favourable effect; + = favourable effect; ?/0 = neutral or unknown effect; - = adverse effect*											
35	Fostering of damp and wet grassland	Agriculture, water	++	++	+	++	+	++	++	+	?/0	++	++	high
36	Protection and (periodic) rewetting of wetlands	Water/ agriculture	++	++	+	++	++	++	++	++	?/0	++	++	high
37	Moorland solar power systems /Agri solar power systems	Water/ agriculture	+	?/0	+	?/0	+	?/0	++	+	++	?/0	?/0	medium
38	Allow succession at spring streams	Water, agriculture	+	?/0	+	+	+	++	?/0	?/0	?/0	+	++	medium
39	Closure, dismantling or control of drainages or drainage channel	Water, agriculture	+	++	+	++	-	+	++	+	+	?/0	?/0	medium
40	Floodplain development and improvement of floodplain habitats	Water, agriculture	++	++	++	++	+	+	?/0	?/0	?/0	++	++	high
41	Fostering floodplains, facilitating bank crossings	Water, agriculture	+	+	+	+	?/0	+	?/0	?/0	?/0	++	+	high
42	Reduction in watercourse maintenance, including the introduction of deadwood into watercourses	Water, agriculture	+	?/0	?/0	+	++	?/0	?/0	?/0	?/0	+	++	low

	Measure	Sector	Effectiveness – Water balance				Effectiveness – Water quality					Site-specific biodiversity		Potential for conflict
			Water supply in dry periods	Groundwater recharge	Water retention in the soil	Delay of runoff	Erosion protection	Water protection (physical/ chemical)	Reduction of nitrogen pollution	Reduction of the phosphorus load	Reduction of PPP usage	Biotope linkage	Biodiversity	
	Text		*++ = significant favourable effect; + = favourable effect; ?/0 = neutral or unknown effect; - = adverse effect*											
43	Reduction of surface sealing	Water	+	++	++	+	+	+	?/0	?/0	?/0	+	+	low
44	Initiating/allowing self-dynamic watercourse development	Water	+	+	+	++	+	+	?/0	?/0	?/0	++	++	medium
45	Optimization or renaturation of polder areas	Water	+	+	+	+	+	?/0	?/0	?/0	?/0	?/0	+	medium
46	Maintaining and restoring open spaces for beavers	Water, agriculture, forestry	+	++	++	++	?/0	+	?/0	?/0	?/0	+	++	medium

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