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Activity 1.7 - Identification of Response Strategy Potential

Deliverable D1.7.1 – Technical outline of the strategic measure bundles (SMB)

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1. Introduction

1.1 Thematic introduction

In agriculture, erosion processes constitute a threat for the productivity of the farmlands on a global level (Pandey et al. 2021). Soil erosion is globally a major cause of significant loss of fertile agricultural top-soil rich in organic matter, surface water contamination by agrochemicals and reduction of crop yields (Reichenberger et al. 2023). Within this context, aeolian erosion driven by strong winds and erosion caused by strong precipitation events must be highlighted.

The aeolian erosion triggered by strong winds can reach high levels on huge agricultural areas, where no hindrances for the winds are present. Wind erosion on agricultural fields can cause crop damage and reduces productivity of the soils by removing fine particles and nutrients (Iwasaki et al. 2024).

The erosion processes caused by strong precipitation events exert also an impact on the agricultural soils, huge amounts of fertile soil substances can be eroded during such extreme weather events and are subsequently transported into brooks and rivers (Halecki et al. 2018, Collins et al. 2021).

Under climate change, drought periods became an increasing threat for the agricultural production, a fact which is also of relevance in the Danube region in Europe. For agriculture, drought poses a major threat to crop and plant productivity, primarily driven by precipitation deficits and extreme hot events (Zhang et al. 2026). Drought periods are one of the most devastating natural disasters, as they are characterized by long duration and high frequency (Lobell et al. 2020). In the project TRANSFER-Danube, an intrinsic focus is put on drought as a challenge for agriculture.

Hence, for the maintenance of high productivity levels in agriculture, with specific regard to winter-wheat and maize, erosion processes and drought periods are to be tackled through the response strategies bundles.

As the mentioned threats (I) erosions processes and (II) drought periods are thematized by the TRANSFER-Danube project consortium, the strategic measure bundles elaborated in Activity 1.7 put a specific focus on potential response strategies within this context.

The potential for response strategies application to mitigate the mentioned processes was identified and is now elaborated in the project. As response strategy to drought periods and against erosion processes for agriculture, three strategic measure bundles (SMB) have been identified, which can be applied by farmers and responsible authorities.

Strategic Measure Bundles (SMB):

(1) Strategic plantation of wind-breaker forest belts within the agricultural fields, in order to reduce wind speed and related evaporation, transpiration and soil erosion processes.

(2) Strategic plantation of buffer-strip forest vegetation along streams, brooks and water courses in order to enlarge areas with increased soil moisture for keeping precipitation water for a longer time in the region (in contrast to fast runoff) and to absorb eroded soil substances.

(3) In cases of huge agricultural areas in the partner countries, extended **forest plantations** can also be implemented to positively affect soils, climate and runoff.

This technical report outlines the aspects of the SMB. They are described with regard to their benefits for agriculture and further effects on human society. Main aspects for their implementation are highlighted. Also, potential disadvantages of SMB are discussed.

1.2 Outline of the specific tasks in Activity 1.7

This is a short outline of the tasks which will be fulfilled in Activity 1.7. All subsequent activities are based on this technical outline of the SMB (D1.7.1)

The analytical process for the response strategy application together with all project partners who implement Pilot Areas (PA) was started in the first project phase. For all PA the fitting strategic measure bundle will be elaborated, based on the respective specific site conditions. The necessary data base provided by each project partner will encompass internal soil and meteorological data, national soil maps and PA maps. The basis for the subsequent analytical processes to be carried out in D1.7.2 and D1.7.3 is provided through the technical outline of the strategic measure bundles (SMB) (D1.7.1).

D1.7.2 will base upon the PA data regarding e.g. soil types derived from Act. 1.1 and the historical meteorological data derived from the Activities 1.4 and 1.5 or geographical PA info like e.g. presence of water courses. The potential for the SMB application will be analysed for all project partners in terms of ecological, meteorological, agricultural and societal indicators. Based on this task, the set of indicators for SMB application suitability will be defined in each PA, which can also be applied in the entire Danube area. Subsequently, for each PA the scope for SMB recommendations will be outlined.

In D1.7.3, the climate-resilient tree species and shrub species portfolios for being used in SMB implementation will be identified for each PA, detailed for each of the three SMB (carried out in D1.7.3).

2. Technical description of the Strategic Measure Bundles

All three strategic measure bundles (SMB) are described on technical level, providing operational guidelines for their application in terms of their benefits and of their optimal spatial extent for achieving efficient impacts.

The three SMB:

I: Wind-breaker forest belts within the agricultural fields

II: Buffer-strip forest vegetation along streams, brooks and water courses

III: Forest plantations

The technical outline of the SMB describes their benefits with regard to erosion mitigation, improvement of the hydrologic regime and further relevant processes within huge agricultural areas. Potential obstacles for SMB implementation are discussed.

2.1 Description of wind-breaker forest belts

Definition of SMB-I: “Strategic plantation of wind-breaker forest belts within the agricultural fields, in order to reduce wind speed and related evaporation, transpiration and soil erosion processes.”

On huge agricultural fields, there is nothing which can provide shelter against wind-erosion of soil substances (=aeolian soil erosion). Winds and storms can speed up and cause erosion of soil substances, especially under dry conditions. Additionally, the winds increase the direct evaporation from the agro-soils and also the transpiration of the crops by disturbing the boundary layer around the evaporating surfaces.

Aeolian soil erosion diminishes the productivity of the agricultural soil formations. But in many cases farmers see obstacles for the establishment of wind-breaker vegetation, as it has to be planted on current farmland which they do not want to give away for this purpose. Hence it is important to increase the awareness about benefits of wind-breaker forest belts (WBF), which is actually an agroforestry system. WBF are playing an important role in reducing the aeolian soil erosion and in water regulation within the agricultural areas. Trees on croplands are mentioned as best agroforestry practice to improve the ecosystem service water regulation (Awazi et al. 2025).

The impact of natural vegetation like the trees in WBF (mosaic landscapes) is seen as positive with regard to various ecosystem services and parameters like e.g. atmospheric temperature (Rosenfield et al. 2022). The practice of planting WBF or shelterbelts is a popular measure to mitigate wind erosion, and the effectiveness of WBF in reducing wind erosion and dust flux has been studied extensively (e.g. Chang et al. 2021; Nordstrom and Hotta 2004).

It has to be highlighted, that WBF in some regions of the Danube River Basin have already a historic tradition, as aeolian soil erosion within agricultural areas also could form a fundamental threat for food-production. For example, in Austria WBF form a specific category of protective forests according to the Federal Forest Act (Austrian Federal Forest Act 1975). Despite this fact many agricultural areas within the Danube River Basin are currently lacking WBF.

For all regions in the Danube River Basin under the land-use category agriculture, it can be stated that an increased application of WBF as response strategy against erosion processes could be of interest. This because of the multitude of benefits which are achieved through the implementation of WBF.

2.1.1. What are the benefits of wind-breaker forest belts?

(A) As first important benefit, the reduction of aeolian soil erosion must be highlighted (Chang et al. 2021). It is the most desired effect of wind-breaker forest belts, as also their name indicates. The forest vegetation reduces the wind-speed above the agro-soils, as it constitutes a natural hindrance for the moving air-mass. As result, the fast winds are moving above the level of the agro-soils and the trees. Hence soil erosion is reduced, as the winds cannot develop their initial erosive potential. Soil substances which are transported despite this effect are deposited around the WBF, especially at leeward sites.

(B) The second benefit can be related to the shadowing effect of the WBF. Especially during the growing season, the shadow-effect of WBF is important. The shadow helps to reduce soil temperature, evaporation and transpiration of the crops. This can help to improve the soil moisture conditions on the agricultural fields. The shadow created by forest vegetation can reduce soil temperature substantially (Koeck et al. 2002; Koeck et al. 2014).

(C) The transpiration of the WBF forest vegetation helps to cool the micro-climate of the agricultural field through the physical process of "evaporative cooling". This is of specific relevance, if the agricultural fields are irrigated, as in those cases more water for evaporation through WBF is available. By this way agriculture helps to cool landscapes until a certain degree.

(D) The WBF help to increase biodiversity of an agricultural region, as it provides habitat for birds, insects and other animals, but also for plants growing at the tree-, shrub- and ground-vegetation level. This impact is of interest, also with regard to the EU-Biodiversity Strategy 2030.

(E) Additionally, soil erosion caused by surface-runoff will be mitigated by the WBF. This because soil substances transported by water during strong precipitation events will be hold back by the WBF.

(F) For WBF, tree species or shrub species can be used, which are suitable for timber or for timber and fruit production. Hence the farmers will be able to have winter-wheat, maize, timber and fruits as products. This aspect has to be highlighted in specific form, as it could constitute an additional motivation for the establishment of WBF. This makes it a true agroforestry concept.

(G) For tree- and shrub species established as WBF, also carbon sequestration can be put into account. If trees are harvested for high-quality timber products also ex situ carbon storage in wood products could be an added benefit.

2.1.2 History of wind-breaker forest belts - the example of Austria

In Austria the history of wind-breaker forest belts (WBF) in agriculture is already long and can be used as an example for the Danube region. In the Marchfeld region (currently a Pilot Area of PP 11 – BOKU University in the project), the first WBF were established back in the 18th century by emperor Maria Theresia in order to re-establish the fertility of the farmlands there. Strong aeolian (=wind-driven) erosion processes caused a fundamental degradation of the agro-soils and it was necessary to tackle this challenge through the strategic establishment of WBF. Hence, WBF were already in the past intended as soil protection measure. WBF since these times are called “Soil-Protection-Installations” in Austria. Marchfeld plays still an important role for Austria’s food supply, above all with regard to winter-wheat and vegetables which are currently grown there on the deep agro-soils.

Since 1975 WBF are regulated on legal level in Austria. Established WBF are transformed from farmlands into forest 10 years after planting (Austrian Federal Forest Act, 1975). For many farmers this was an argument against the establishment of WBF on their fields, as there was no chance to transform the areas back into agricultural land, also if a specific site of a WBF turned out as being not suitable in terms of the initially intended effects.

Back in 2023 the creation of “multi-purpose-hedges” (MPH) was initialized as specific form of WBF in Austria (Steiner et al. 2023). Those have to fulfill multiple purposes, above all biodiversity-enhancement, erosion-mitigation (aeolian and precipitation-driven), improvement of the micro-climate of the site, creation and interlinking of habitats, etc. Within MPH there are tree-species, shrub-species and ground vegetation combined in a spatial unit. The basic functionality of MPH is identical with WBF. The crucial difference is, that MPH will not be declared as forest area according to the Federal Austrian Forest Act (1975). This implies that the farmers have to follow the recommendations of e.g. the Lower Austrian Agricultural District Authority, who are responsible for planning, implementation and maintenance of MPH. If this is fulfilled, farmers can receive all the benefits of WBF established in the specific form of MPH, which also includes funding of the establishment and maintenance of MPH (funding by hectare of a created MPH per year) (Steiner et al. 2023).

Due to these facts MPH are currently established above all other options as WBF on Austrian farmlands. This is a rather new development, as the concept of MPH exists since 2023. It is an adaption to modern times, where besides the soil protection functionality of WBF also carbon sequestration, balancing of the hydrological regime and biodiversity functions come into play.

2.1.3 The dimensions of WBF – spacing and tree height

For being functional within the context of the intended effects like erosion mitigation or hydrologic functions, the spacing and tree height of WBF has to be considered. This will be of crucial importance for farmers as it should be oriented on the trade-off between farmland extension and the positive impacts and effects on it created through WBF.

For the specific spacing of the WBF there has to be stated, that the vertical extension (growth height) of the established tree species should not exceed a certain threshold. This because e.g. 40 m high trees would (I) create too much shadow on the farmlands and (II) would be prone towards wind-throw themselves. Hence, the growth-height of tree species established within a WBF has to be tailored specifically to the agricultural sites where they will be established.

The questions regarding spacing and growth height of WBF have to consider (I) the wind-exposure of the specific farmland, (II) the main-direction of winds, (III) the soil types and crops planted at the site, and (IV) the dimensions of the agricultural machinery in use, and (V) the tree species used for the WBF. The soil-protection functionality of the WBF has to be put into the centre of the decision process regarding the spacing questions. Of course, it is not possible to define an exact value for all the farmlands within the Danube region.

The recommended height of trees in WBF can hence be defined with a range between 8 m and 20 m. The selection of the intended tree-height can be defined by the farmers within each agricultural area. After the WBF has reached the pre-defined top-height, trees can be harvested. But instead of cutting the whole WBF, only parts should be harvested in order to keep the functionality of the WBF. The related silvicultural management concept is “strip-wise coppice or coppice with standards” (Hochbichler et al. 2015).

The recommended percentage of harvesting in WBF is hence defined between 25 – 33 % of the trees. After 3 – 5 years, - depending on the regrowth development of the trees and shrubs - the next part of the WBF can be harvested. This would allow the continuous functionality of the WBF. The fully regeneration of the WBF would be reached after 6 to 12 years. This strategic harvesting concept can be kept over years in order to allow the sustained functionality of the WBF. It also could be described as continuous-cover WBF system. Different forms of WBF are displayed (Tab 2.1.1).

Table 2.1.1: Variable forms of WBF.

Variable forms of wind-breaker forest belts (WBF)		
Combination	**Tree growth height**	**Harvest products**
Trees and Shrubs	High stem trees, low growth height	Fruits and firewood
Trees, Shrubs & Ground vegetation (MPH)	High stem trees, low growth height	Fruits and firewood
Trees, Shrubs & Ground vegetation (MPH)	High stem trees, medium growth height	Fruits, high-quality timber, herbs

If a farmer decides to apply WBF as economically oriented agroforestry concept, like e.g. the use of maize or winter-wheat on the farmland and the use of e.g. Sweet Chestnut (*Castanea sativa*) as combined fruit- and timber tree species, the intended height of Sweet Chestnut in the WBF can specifically defined. Also, Common Walnut (*Juglans regia*) or Wild Cherry (*Prunus avium*) could be used that way. This in terms of the maximisation of fruit- and timber yield from these tree species in combination with the maximisation of the crop-yield (winter-wheat or maize). This example makes it clear, that each specific situation of a farmland and of the intended economic concept will influence the spacing of WBF in terms of growing height of the trees within the WBF and of spacing between the WBF rows (see also Tab. 2.1.1).

The spacing between the WBF rows should be adapted to the regional conditions and needs of the farmers. The distance between the WBF-rows should not be too close, but it also should not extend too far. The guiding principle for estimating the fitting distance between the WBF-rows are (A) an efficient reduction of the erosive force of winds and (B) the positive impact on the agricultural crop-yield. Reported distances between WBF-rows range between 80 m and 300 m and are dependent on the regional conditions according to wind-exposition, wind-speed and soil conditions. The minimum width of WBF should be 5 m. As basic rule, WBF should be placed rectangular to the main wind direction.

Keeping the WBF at their intended site

For agricultural interests it is of importance that WBF are growing at their allocated sites and do not extend into the farmland. For reaching this purpose the normal agricultural tillage activities are enough, like ploughing or soil-milling at the farmland along the WBF. Within this context it is highlighted to keep a strip of about 2.5 m beside the WBF for operation activities with agricultural machinery and as buffer between farmland and WBF-forest vegetation. This strip should be present at both sides of the WBF and can be planted with ground-vegetation species like *Trifolium repens*, which only reaches very low heights and therefore machinery can move on it. This plant species is also useful for bees and humblebees as nectar provider.

2.1.4 Which plant species are used in WBF?

Classically, a combination of tree species and shrub species is used for the creation of WBF. For achieving the full spectrum of soil protection functionality, trees together with shrubs yield the maximum effect, as there can be built a true wall of vegetation for breaking wind speed. The trees provide shelter in the top-level of the WBF, while the shrubs close the space between the soil-level and the lower parts of the tree crowns.

For the modern MPH also ground vegetation is integrated and used, which enhances the functionality in terms of biodiversity. At each specific agricultural site, the question about the tree- and shrub-species to be used has to be put into the centre of the planning process. This becomes important especially under climate change conditions, which causes shifting suitability of tree- and shrub species on a specific site.

For establishing WBF, the fitting tree or shrub species will be defined for each Pilot Area of the TRANSFER-Danube project. This will be part of Deliverable D1.7.3. and hence will be provided later in the course of the project, as specific technical report.

2.2 Description of buffer-strip forest vegetation along streams and water courses

Definition of SMB-II: “Strategic plantation of buffer-strip forest vegetation along streams, brooks and water courses in order to enlarge areas with increased soil moisture for keeping precipitation water for a longer time in the region (in contrast to fast runoff) and to absorb eroded soil substances.”

In the past, streams or water courses like e.g. brooks in agricultural fields were in in many cases designed to channel precipitation water as fast as possible into the nearest stream, in our case the Danube River. In some areas of the Danube river-basin this strategy resulted in quasi technically constructed channels, which sometimes also tended to be linear in shape. Some of them were even constructed with concrete so that the stream water has no more connection with the surrounding soils and flows fast to the nearest river.

This resulted in a relative fast runoff of precipitation water. The water did not remain in the agriculturally used region. Under climate change conditions, this situation is not desirable anymore, as water became scarce in many areas, especially in the lowlands used for agricultural production.

The creation of buffer-strip forest vegetation along streams, brooks and water courses can provide a solution for this situation. Why that?

2.2.1 What are the benefits of buffer-strip forest vegetation?

If the water courses are naturally open and not flowing within concrete streams, the buffer-strip forest vegetation can use the soil water along them. Soil water content along water courses is in general higher than on other agricultural sites. Those soil types are influenced by groundwater related to the streams. In most of the cases these are true Fluvisols (WRB 2015), which are also known as alluvial soils or floodplain soil types.

The surplus of water content in Fluvisols creates a specific situation in terms of site conditions, which provides more water for the transpiration process of the shrub- and tree species growing at these sites. Of course, this situation also influences the tree- and shrub species spectrum which can grow there.

The higher amount of soil water which is available for transpiration on the Fluvisol sites (= alluvial soil sites) is of interest for improving the hydrologic regime within agricultural used areas:

(A) Soil substances which are eroded through strong precipitation events can be held back by buffer-strip forest vegetation and hence are not lost in the Danube River. In some cases, they may even be re-distributed on the farmlands through ploughing. This is one of the most important effects of BSF and also helps to keep a high water quality standard of the related water course.

(B) The transpiration of forest vegetation provides the cooling of the surrounding area through "evaporative cooling".

(C) Through the transpiration processes of the trees and shrubs growing in the buffer-strips, the resulting increased relative humidity of the local air-mass creates more dewfall, which is a useable water resource for the crops.

(D) Both cooling of the air-mass and increased dew result in an improved hydrologic situation for the agricultural crops like in our case winter-wheat and maize. The shadow of BSF provides cooling of the agro-soils in close distance to the tree- and shrub belt.

(E) During strong precipitation events, soil erosion processes caused by water streams (brooks or rivers) can be mitigated or avoided. Thus, adjacent farmland is protected from deep soil erosion through functional BSF.

(F) Additionally, buffer-strip forest vegetation acts as wind-breaker for mitigating aeolian soil erosion.

(G) The intrusion of nutrients and chemicals like pesticides into water courses can be mitigated through BSF (positive effect on water quality).

(H) BSF help to promote biodiversity on both flora and fauna level.

(I) BSF can create carbon sequestration, especially if the harvested timber is used for long-living products.

All these benefits created by buffer-strip forest vegetation (BSF) are of interest for agriculture and additionally for the whole society in terms of various ecosystem services. This is the reason why there exist many examples for the creation of BSF, both in agriculturally used land as well as in forested areas, around the world. In the following chapter “History of BSF” the scientific background will be outlined additionally to some further historic facts.

2.2.2 History of BSF along water courses

Buffer-Strip Forest (BSF) vegetation along water courses (= the riparian area) has globally a profound history as Best Practice example in both forested and agricultural watersheds. It is in essence intended as means to mitigate or avoid the intrusion of sediments into water courses but also provides further benefits like cooling of the water body, improvement of the hydrologic regime of an area or habitat for flora and fauna. The various aspects of BSF in terms of their potential functions is described here.

The effectiveness of riparian buffer strips as retention area for sediments and nutrients has been proved by various studies (Wallbrink et al. 2002). The riparian area is the transition between aquatic and terrestrial characteristics of soil, water, vegetation and landform. As such, they contain unique species combinations and are especially important to protecting water quality as well as the food chain and physical structure of aquatic habitats. In the USA, state best management practices normally require buffer strips of one or more tree lengths on both sides of perennial stream channels to protect the stream and riparian area (Twery and Hornbeck 2001).

Vegetative filter strips like BSF along water courses are globally the most widely implemented mitigation measure to reduce transfer of sediments (Parsons et al. 1991; Park et al. 1994; Helmers et al. 2008) and other pollutants (Douglas-Mankin et al. 2021) to surface water bodies via erosion and runoff. Riparian vegetation has been planted in the riparian zone of the water courses to alleviate the effect of non-point source pollution through the interception of nutrients and contaminants (Dosskey et al. 2010). The reduced transfer of sediments into water courses is already a positive effect on ecosystem service water regulation.

In TRANSFER-Danube, BSF are mentioned as specific type of agroforestry concepts and their impact on the hydrologic regime of an agricultural area is highlighted. The transpiration of forest vegetation provides the cooling of the surrounding area through “evaporative cooling” (Awazi et al. 2024) and the shadow of forest vegetation exerts a cooling effect for the surrounding agro-soils and the forest-soils (Koeck et al. 2002; 2014). Both effects together can provide an improvement of the hydrologic regime of an agricultural site through e.g. dew-fall enhancement.

The effect of BSF as means for mitigating erosion processes during strong precipitation events has to be highlighted. This can be of essential interest for agriculture, as the farmlands along water courses are protected from deep soil erosion.

Findings indicate, that agroforestry plays an important role in water regulation through the improvement of soil carbon and soil properties, which enhances soil water both in quality and quantity. As best agroforestry practices for water regulation, buffer zone agroforests are mentioned (Awazi et al. 2024). It was uncovered that monoculture farming systems of rice, maize and soybeans had very limited water optimization and use efficiency when compared to more sustainable and integrated agroforestry systems, which had better water optimization and use efficiency (Li et al. 2021).

BSF also have an essential impact on biodiversity indicators. The specific species combination at tree-species, shrub-species and ground-vegetation level is characteristic for riparian forest communities (e.g. Willner and Grabherr 2007) and can be described as diverse. The effect of BSF on the flora has to be highlighted, there can grow various ground vegetation species, shrubs and trees which are of importance for e.g. insects as pollinators, for humans as medicinal plants and for bees or bumblebees as nectar plants. The high values of the indicators for the presence of medicinal and nectar plants are likely linked to fertile growing conditions, which are typical for riparian forest stands (Saklaurs et al. 2022) like given in BSF.

The fauna within BSF is also characteristic and encompasses various species. For example, woody vegetation along the riparian zone is generally associated with the richness-related metrics of aquatic macro-invertebrates. Specifically, *Ephemeroptera*, *Plecoptera* and *Trichoptera* richness shows a directly proportional relationship with riparian forest area and width, as e.g. exemplified in some study areas (Forio et al. 2020). This report just points out the thematic field of biodiversity within BSF as decision criteria and does not make a claim for describing a whole set of flora- and fauna species there.

The positive effect of BSF on biodiversity is an important ecosystem service and has to be put into relation with the EU-Biodiversity Strategy 2030 or - as part of it - also with the EU-Nature Restoration Regulation (EU-Nature Restoration Regulation 2024), which both are of specific relevance within the project context in the Danube Region Programme. In Austria this thematic context is covered by the Austrian Floodplain Strategy (Österreichische Auenstrategie 2023).

2.2.3 The dimensions of BSF – spacing and tree height

For creating buffer strip forest vegetation (BSF) it is necessary that water courses are present within the agricultural area. Hence, the question regarding spacing is in essence determined by this fact.

The spacing of the BSF along the water courses can be variable. On each side of the water course a minimum of 5 - 7 m BSF-width should be given in order to achieve the intended effects. Depending on the specific site conditions and intentions of the regional farmers, the BSF-width can also have larger dimensions. In some cases, where historical floodplain forest ecosystems are restored – for example according to the EU-Nature Restoration Regulation (EU-Nature Restoration Regulation 2024) - the dimension of BSF can be adapted according to the specific trade-off between the involved farmers and the funding authority. In Austria, for example, the "Floodplain-Strategy" is currently implemented in order to partially restore historic floodplain forest areas (Austrian Floodplain Strategy 2023).

In most of the farmlands the width of the BSF will be rather smaller for balancing both the need of the BSF-effects with the dimensions of the agricultural fields.

The height of the trees and shrubs within the BSF can be adapted to their site-specific purpose. Again, tree species and shrub species should be established together in order to achieve the best BSF-effects. Following some potential variants are displayed (see overview in Tab. 2.2.1).

Variant A: Focus on the BSF-effects, timber use for firewood

This variant can be established through the application of the silvicultural system "coppice", actually a "strip-wise coppice or coppice with standards" system (Hochbichler et al. 2015). This involves the definition of the height of the trees by the farmer, and should be minimum 8-12 m. The trees can be harvested after reaching the intended growth-height. In order to keep a sustained functionality of the BSF, yielding should be partially, like e.g. cutting 30-50 % of the BSF trees per year. The interval between the cuts should be minimum 3-5 years for achieving the intended effects. The selected tree-species should be able to regenerate through "coppicing" (the trees are able to grow from their stamp or roots after cutting measures). The tree- and shrub species which are growing in the BSF can be used as firewood.

This variant A is a specific agroforestry concept with medium potential for value-creation.

Variant B: Focus on BSF-effects, tree use for high-quality timber, shrub use for fruit production

Tree species with potential for high-quality timber are selected for the BSF-sites. They are established through planting after each cutting measure in order to guarantee high quality of timber. The available tree species spectrum is defined site-specifically (see D 1.7.3) for each Pilot Area. The growth height of the trees is defined by the involved farmers and depends on the intended amount of high-quality timber (meters of log-wood) to be achieved. It should be at least 12 m but can be of course larger, if so desired.

The trees can be harvested after reaching the desired growth height and diameter in breast-height. Again, it is recommended to abstain from clear-cutting the BSF in order to sustain their functionality. As alternative, the single tree cutting method or the group selection system can be applied. During one cutting measure, between 30-50 % of the trees can be harvested. The interval between the cuts should be minimum 3-8 years.

The shrub species can be selected according to the intended fruits or flowers to be yielded but must be part of the shrub-species spectrum of BSF sites (will be detailed in D 1.7.3). The yielding of the shrub products can include flowers, fruits and timber for fire-wood after cutting. Shrub species can achieve growth-heights ranging between 4-8 m but of course can be established according to intended growth-heights for e.g. harvesting purposes.

This variant B hence is a specific agroforestry concept with high potential for value-creation.

Variant C: Focus on BSF-effects, no timber use at all, BSF-establishment for biodiversity purposes, restoration of natural floodplain forest conditions

This specific variant is a potential solution for areas which were selected for nature restoration activities (EU-Nature Restoration Regulation 2024). As such also historic floodplain areas are of interest for being restored. They only can be planned and established if an agreement between involved farmers and funding authorities was reached. If this basic condition is given, the planning process can begin and will have to encompass questions about the spacing of the intended floodplain forest area, potential construction measures like opening of concrete stream beds (etc.) and which tree- and shrub species will be established there.

Agriculture would receive the positive effects of the extended BSF, which is a floodplain forest area.

Under current conditions, both the Austrian Pilot Areas Marchfeld and Tullnerfeld are situated adjacent to the Danube River where extended floodplain forest ecosystems are established. In case of Marchfeld it is the Danube Floodplain National Park, hence nature conservation is the focus there. In case of Tullnerfeld it is the Tullner floodplain forest area, which is under conventional timber forestry use within a Natura 2000 area. Both Pilot Areas of course receive the positive effects of the adjacent extended floodplain forest areas, like e.g. increased relative humidity of the local airmass.

This variant C hence is a specific nature restoration concept with high potential for biodiversity indicators. It encompasses of course the mentioned positive effects of BSF on agriculture.

Table 2.2.1: Different forms of Buffer-Strip Forest vegetation (BSF).

Forms of buffer-strip forest vegetation		
Variant	**Focus of BSF**	**Width of BSF** (each side of the stream)
A	Fire-wood	minimum 5 m width
B	High-quality timber, fruits	minimum 5 m width
C	Nature protection, biodiversity	Width according to agreement

The case of Drainage Channels

For waterlogged soils on farmlands, drainage channels were constructed to allow the cultivation of any envisaged crops. The term “waterlogged soils” encompasses e.g. soil types like Gleysols, Stagnosols or Planosols (WRB 2015). In case of stronger precipitation events such soils are “swamped”, what can make the cultivation of any agricultural crops impossible. For achieving a status of the farmlands, which allows crop cultivation at such sites, drainage channels were constructed to transport the surplus of soil water to the nearest brook or river. Those drainage channels must remain functional, also under climate change. Hence, they are no suitable sites for the establishment of BSF, as the growing forest vegetation (trees and shrubs) could clog the drainage channels. Due to this situation, only natural brooks, rivers, other water courses or lakes should be used for the establishment of BSF. Drainage channels in most of the cases will have to remain free from forest vegetation, as they are periodically cleaned for remaining in a functional condition.

Closing sentence

It has to be highlighted that <u>spacing</u> of BSF depends on the occurrence of water courses. <u>Growth-height</u> of the trees and <u>BSF-width</u> depend on the specific agroforestry concept selected - hence those questions are answered through the involved farmers.

Along the BSF it is of interest to keep an area of about 2.5 m width for operation activities with agricultural machinery and as transition-zone strip between the BSF vegetation and the farmland with crops. For keeping the BSF within its spatial limits, the normal tillage activities like ploughing or soil-milling on the farmland should be enough. If ploughing is not applied, the recommendation is given to apply soil-milling on the farmland adjacent to the transition-zone strip. This management measure should avoid, that tree roots extend from the BSF into the farmland.

2.2.4 Which plant species are used in BSF?

For the buffer-strip forest vegetation (BSF), the potential tree species set differs from the wind-breaker forest belts. This, because the sites provide a higher water regime class than the surrounding agricultural sites. This situation requires an adaptation of the potential tree species set which can be used. The selection of the fitting tree species for BSF in each Pilot Area will be central focus of D.1.7.3.

2.3 Description of forest plantations

Definition of SMB-III: "In cases of huge agricultural areas in the partner countries, extended forest plantations can also be implemented to positively affect soils, climate and runoff."

Forest plantations (FP) on historic agricultural lands are a global means for intensified timber production and can encompass various tree species to be cultivated.

For the creation of FP there has to be given a substantial economic aspect regarding the use of timber or fruits (or both) of the planted trees. Hence the economic aspect of FP is prior for farmers. In the Danube Region most of the historic forest plantations were using Poplar species (*Populus sp*.) for being cultivated in FP (Tullus et al. 2026). Timber stemming from Poplar species cultivated in FP is used for pulp wood, wooden boxes for agricultural products, etc.

On global level, tree species cultivated in FP are e.g. Eucalyptus species (*Eucalyptus* sp. - Dos Santos-Mateus et al. 2026), Pine species (*Pinus sp.*), Japanese Cedar (*Cryptomeria japonica*) in Japan (Miyamoto and Takamura 2026) or Teak

(*Tectona grandis*) like e.g. given in diverse Asian countries like e.g. Thailand (Chayaporn et al. 2021), in Costa Rica and Panama (Nölte et al. 2022) or Mexico (Minoche et al. 2017).

2.3.1 What are the benefits of forest plantations on agricultural land?

In huge agricultural areas, where only crops are planted and form a uniform landscape, the presence of forest plantations (FP) can provide positive effects for agriculture. For the TRANSFER-Danube project, the interest regarding forest plantations in agricultural areas is, besides their – prior - economic aspects, additionally related to their effects on the hydrologic regime of the area, to mitigation of soil erosion processes and to biodiversity aspects. Some benefits of FP are similar to e.g. the buffer-strip forest vegetation or the wind-breaker forest belts, just because of the basic forest-effects on e.g. hydrological level.

(A) Above all, the economic aspect of FP has to be highlighted. The most important benefit of FP is given by their economic dimension. Only if trees can create a substantial increase of income for the farmers (timber, fruits or also timber & fruits), they will be planted in FP on agricultural land.

(B) FP can help to mitigate soil erosion triggered through strong winds, as it can act similar like a wind-breaker forest belt (this is also depending on the FP spatial positioning in the farmland).

(C) Soil substances eroded through strong precipitation events can be trapped by FP, especially if those are placed on the specific fitting sites.

(D) The transpiration of forest vegetation provides the cooling of the surrounding area through "evaporative cooling".

(E) Through the transpiration processes of the trees and shrubs growing in the buffer-strips, the resulting increased relative humidity of the local air-mass creates more dewfall, which is a useable water resource for the crops.

(F) Both cooling of the air-mass and increased dew result in an improved hydrologic situation for the agricultural crops like - in our case - winter-wheat and maize. The shadow of FP provides cooling of the agro-soils in close distance and to the forest-soils within their extension.

(G) Biodiversity indicators can be improved by FP, what can be related to both flora and fauna aspects.

(H) Carbon sequestration achieved through forest vegetation, above all in case of long-lasting high-quality timber products.

2.3.2 History of forest plantations & tree species aspects

In Europe, the use of classical forest plantations on previous agricultural lands is not so common as e.g. in Latin America. This fact can potentially be related to tree species aspects. If there are renown tree species present in a country, which can yield substantial income increase through high-quality timber, this situation could act as motivation for farmers to establish FP on their farmlands.

One example for such a situation is the tropical tree species Teak (*Tectona grandis*), which is currently grown in FP in many countries on the planet. Cases are reported e.g. from Costa Rica and Panamá, where *Tectona grandis* is the most planted species in FP, occupying 49 % and 64 % of the forest plantation area (Nölte et al. 2022). The presence of Teak forest plantations also was reported from Mexico (Minoche et al. 2017), Ghana in Africa (Kumi et al. 2021) and diverse Asian countries like e.g. Thailand (Chayaporn et al. 2021).

In Europe, currently Poplar (*Populus sp.*) plantations are the most common form of FP (e.g. Tullus et al. 2026).

Silvicultural management in forest plantations as key to success is mentioned in various studies. The results of Kumi et al. (2021) from a Teak plantation analysis in Ghana show, that management practices have a significant effect on stand characteristics as well as on the soils on which FP stands grow - therefore forest managers must endeavour to apply intensive management practices to optimize the FP benefits. The stand density management diagram designed for Teak (*Tectona grandis*) FP in the Mexican state of Tabasco is particularly useful for planning and assessing the consequences of alternative silvicultural management regimes (Minoche et al. 2017).

Another aspect of FP is increased biodiversity in comparison to classical agricultural landscapes. According to Tullus et al. (2026), mature hybrid Poplar (*Populus sp.*) plantations are relatively species-rich and support taxa which are characteristic for European Poplar stands, including species valuable for conservation, thereby enhancing connectivity and providing stepping-stones for forest species in agricultural landscapes.

Under current climate change conditions, a further aspect of FP comes into the focus of interest, and this is carbon sequestration. For example, Chayaporn et al. (2021) concluded, that the management of Teak forest plantations and the inclusion of carbon storage in harvested timber products generated through different activities of forest management plays an important role in climate change mitigation.

Tree species aspects

As mentioned above, valuable tree species are an important factor for motivating farmers to establish FP on their farmlands. Hence, the question regarding tree species used in FP is already posed now in this Deliverable the first time and of course will be detailed in Deliverable D1.7.3.

An interesting tree species for FP is Sweet Chestnut (*Castanea sativa*) as it yields both fruits and high-quality timber. This is an aspect with specific relevance for agroforestry concepts. The increasing relevance of Sweet Chestnut in current times was highlighted e.g. by (Conedera et al. 2004), who pointed out that the evolution of the chestnut market confirms the potential of this resource for both traditional products and new services and goods related to organic-food and environmentally friendly products. The fruits of Sweet Chestnut can be used in variable ways, even for brewing beer like currently in Corsica.

Historically, the Romans may have introduced the idea of systematically cultivating and using Sweet Chestnut with regard to fruit-use. The greatest interest in the management of Sweet Chestnut for fruit production most probably developed after the Roman period and could be associated with the socio-economic structures of medieval times. It was then that self-sufficient cultures based on the cultivation of Sweet Chestnut as a source of subsistence were formed (Conedera et al. 2004b).

From Chile a timber-use focus was reported, where the mixture of Sweet Chestnut with arboreal species like e.g. Common Oak (*Quercus robur*) or Wild

Cherry (*Prunus avium*) in FP resulted in better timber quality of Sweet Chestnut (Loewe-Munoz et al. 2023).

Another tree species with potential of a combined fruit- and high-quality timber use is Common Walnut (*Juglans regia*). Again, this tree shows suitability for being cultivated in FP. Common Walnut is an economically important, long-lived, perennial tree cultivated worldwide for high-quality timber, edible nuts, and several secondary products (Pollegioni et al. 2020).

In the context of TRANSFER-Danube we highlight the potential to use both fruits and high-quality timber from Sweet Chestnut and Common Walnut, cultivated in FP as being a special agroforestry benefit. Specific silvicultural concepts for managing such plantations will have to be screened or elaborated. We just point out the potential of both tree species for cultivation in FP within the project region. Details about tree species suitability within the specific Pilot Areas will be given in Deliverable D1.7.3.

2.3.3 Spacing and height of trees in forest plantations

Regarding the question, which spacing and height for trees within forest plantations (FP) can be selected, it only can be stated that the answer is depending on the tree species and silvicultural concept selected for a FP. Due to this situation, there can arise various different forms of FP (Tab. 2.3.1). The overview given in this table just displays some potential purposes of FP and does not encompass all possibilities. The different concepts result in differences regarding spacing of planted trees, target growth-height etc. It is mentioned that for timber yield focus in FP only high-stem trees will be envisaged (Tab. 2.3.1).

Table 2.3.1: Overview about different forest plantation concepts.

Forest Plantation Concepts		
A Fruit yield focus	A1 High-stem trees	A2 Low-stem trees
B Fruit & timber yield focus	B1 High-stem trees	B2 Low-stem trees
C Timber yield focus	C1 Short rotation	C2 Medium rotation
	C3 Fire-/Pulp- timber	C4 High-Quality timber

We only state in this technical outline, that for the efficient establishment of FP, the questions regarding spacing in the course of tree planting, thinning measures and the intended growth height of the trees have to be answered. A sound silvicultural concept is essential in order to establish economically successful FP on agricultural lands (Minoche et al. 2017, Chayaporn et al. 2021).

2.3.4 Which tree species can be used in forest plantations?

Some aspects of tree species to be used in FP were already highlighted. In current times, there are dominating Poplar species (*Populus sp*.) in FP in parts of Europe (Tullus et al. 2026). On international level several tree species cultivated in FP are mentioned in literature, like e.g. Teak (*Tectona grandis*) in tropical areas (Nölte et al. 2022, Minoche et al. 2017, Kumi et al. 2021). Globally, also the wide use of Pine species (*Pinus sp*.) and Eucalyptus species (*Eucalyptus sp.*) in FP was reported (Dos Santos-Mateus et al. 2026).

We have highlighted the specific interest related to Sweet Chestnut (*Castanea sativa*) and Common Walnut (*Juglans regia*) being cultivated in FP within the Danube region. This because of the double-provision of goods (fruits and high-quality timber) becoming possible with these two tree species grown in FP (Conedera et al. 2004, Loewe-Munoz et al. 2023). So, FP with those two tree species would be intrinsically agroforestry concepts.

Of course, a multitude of different tree species could be used in FP, always depending on ecological site factors, climate and above all – the economic interests related to FP. All further and more detailed aspects regarding tree species which could be used in FP within the Pilot Areas of the TRANSFER-Danube project are being elaborated in Deliverable D1.7.3.

3. Discussion of SMB aspects

The application of strategic measure bundles (SMB) in agricultural areas within the Danube Region is of crucial interest under climate change. SMB were defined in order to establish a response strategy for agriculture under current climate change conditions, above all to respond to drought conditions and erosion processes. The overall purpose for the application of SMB in farmlands is the improvement of the hydrologic conditions and the mitigation or avoidance of soil erosion processes.

The related benefits which can be achieved through the application of SMB are diverse. On *hydrologic level* the evaporative cooling effect achieved through forest vegetation within SMB was highlighted, leading also to increased relative humidity of the local airmass and resulting increased dewfall. On the *soil erosion level*, both aeolian soil erosion caused by strong winds and soil erosion caused by water in the course of strong precipitation events can be mitigated or avoided. On the *biodiversity level*, the presence of forest vegetation in SMB increases biodiversity on both flora and fauna level and hence help to achieve positive impacts on agriculture and – additionally - on biodiversity-goals defined e.g. in the EU Biodiversity Strategy 2030. On *economic level*, with the application of SMB in many cases additional income can be created through e.g. high-quality timber, fire-wood timber or fruits. Sometimes also funding for the establishment of SMB can be achieved, like e.g. in the case of wind-breaker forest belts in Austria (multi-purpose hedges - MPH), where the farmers receive funding per year and hectare of an established MPH. On the *level of carbon-sequestration*, the effect of SMB forest vegetation as carbon storage, especially if harvested and used long-term as high-quality timber, must be highlighted.

But in light of so many benefits created by SMB, why can there still be identified reluctance for their establishment? This question is of course the main theme to be addressed in the course of knowledge transfer activities. Farmers see above all the reduction of farmland caused by the establishment of SMB. This could be the main hindrance. But, also the potential extension of forest vegetation roots growing within SMB into the farmland is an argument which is periodically stressed by farmers.

Of course, those hindrances have to be confronted in order to strengthen the potential to establish SMB within agricultural areas. The first hindrance can be tackled through e.g. funding the application of SMB, like it is provided in Austria for the establishment of MPH. Also, information about the benefits of SMB for agriculture will help to overcome this hindrance.

In the second case, the extension of tree- or shrub roots into farmland can be avoided through the application of specific tillage measures, like e.g. ploughing of the agro-soils within the farmland, which in many cases is a common agricultural activity and does not require additional efforts. In other cases, milling of the agro-soils adjacent to the SMB area can be applied for avoiding the lateral tree-root extension into the farmlands.

Despite the hydrologic benefits created through the application of SMB, the thematic field of irrigation is in the centre of interest for agriculture, to ensure high crop yields also under drought conditions. The theme was discussed in the course of the First Austrian Stakeholder Event and farmer representatives stated the current demand for irrigation for specific crops like e.g. vegetables. Also, for winter-wheat and maize, irrigation could become necessary under given circumstances.

For further Stakeholder-Events in the project TRANSFER-Danube it will be necessary to discuss the benefits of SMB and potential hindrances for the willingness to establish them in current farmlands. An open discussion will help to integrate all necessary positions and to achieve an outcome with benefits for agriculture.

4. Conclusions

The application of strategic measure bundles (SMB) in agriculture can provide various benefits. The described SMB yield main ecosystem services for which they are established. Additionally, all SMB create benefits on the level of further ecosystem services.

SMB-I wind-breaker forest belts (WBF) are established as soil protection installations. They can mitigate soil erosion processes, above all aeolian (= wind-driven) erosion but also water-driven soil erosion during strong precipitation events.

SMB-II buffer-strip forest vegetation along streams (BSF) can hold back soil substances which are eroded through strong precipitation events hence they act as a trap for sediments and agro-chemicals. The transpiration of BSF growing on the relatively wetter Fluvisols (= alluvial soils) provide higher relative humidity of the local airmass and hence increase dewfall.

SMB-III forest plantations (FP) have the most important benefit through their economic dimension. Only if trees can create a substantial increase of income for the farmers (timber, fruits or timber & fruits), they will be planted in FP on agricultural land.

All three SMB additionally provide forest effects, like cooling of the top-soils through their shadows, evaporative cooling through transpiration, positive effects on biodiversity on both flora and fauna level and also carbon sequestration for climate change mitigation.

Despite the multitude of benefits of SMB, farmers will have to overcome hindrances for their implementation. This challenge can be tackled through knowledge-transfer activities for being aware about the benefits created through SMB. If specific management measures are carried out, like e.g. keeping WBF or BSF within their allocated spatial extension, the acceptance for SMB application among farmers will potentially increase.

5. References

Austrian Federal Forest Act (1975). Österreichisches Forstgesetz 1975. www.ris.bka.gv.at

Awazi, N.P., Njamnjubo, N.A., & Ambebe, T.F. (2024). Agroforestry for ecosystem services: Assessing the role of agroforestry for water regulation. Forestist 75, 0032, doi:10.5152/forestist.202424032.

Chang, X., Sun, L., Yu, X., Liu, Z., Jia, G., Wang, Y., Zhu, X., (2021). Windbreak efficiency in controlling wind erosion and particulate matter concentrations from farmlands. Agriculture, Ecosystems & Environment 308, 107269. https://doi.org/10.1016/j.agee.2020.107269.

Chayaporn, P., Sasaki, N., Venkatappa, M., Abe, I. (2021). Assessment of the overall carbon storage in a teak plantation in Kanchanaburi province, Thailand– Implications for carbon-based incentives. Cleaner Environmental Systems 2, 100023.

Collins, A.L., Upadhayay, H.R., Zhang, Y., Olde, L., Sint, H. (2021). Agricultural land lacks resistance to water erosion during the wettest winters of the past decade. Agriculture, Ecosystems & Environment 389, 109713.

Conedera, M., Manetti, M.C., Giudici, F., Amorini, E. (2004). Distribution and economic potential of Sweet Chestnut (*Castanea sativa* Mill.) in Europe. Ecologia Mediterranea, tome 30 n°2, 2004. pp. 179-193.

Conedera, M., Krebs, P., Tinner, W., Pradella, M., Torriani, W. (2004b). The cultivation of *Castanea sativa* (Mill.) in Europe, from its origin to its diffusion on a continental scale. Veget. Hist. Archaeobot. 13:161–179.

Dos Santos-Mateus, K., Paiva, W.L.S., Braga, D., Ribas, C.R., Queiroz, A.C.M., Zanetti, R. (2026). Formicides application in Eucalyptus plantations and their temporal effects on composition of ground-dwelling ants in adjacent forest fragments. Acta Oecologica 130, 104148.

Dosskey, M.G.; Vidon, P.; Gurwick, N.P.; Allan, C.J.; Duval, T.P.; Lowrance, R. (2010). The role of riparian vegetation in protecting and improving chemical water quality in streams. Jawra J. Am. Water Resour. Assoc. 2010, 46, 261–277.

Douglas-Mankin, K.R., Helmers, M.J., Harmel, R.D. (2021). Review of filter strip performance and function for improving water quality from agricultural lands. Trans. ASABE. 64 (2), 659–674. https://doi.org/10.13031/trans.14169.

EU-Nature Restoration Regulation (2024). Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 (Text with EEA relevance). http://data.europa.eu/eli/reg/2024/1991/oj

Forio, M.A.E., De Troyer, N., Lock, K., Witing, F., Baert, L., De Saeyer, N., Rîs, G., Popescu, C., Burdon, F.J., Kupilas, B., Friberg, N., Boets, P., Volk, M., McKie, B.G., Goethals, P. (2020). Small Patches of Riparian Woody Vegetation Enhance Biodiversity of Invertebrates. Water 12, 3070; doi:10.3390/w12113070.

Halecki, W., Kruk, E., Ryczek, M. (2018). Loss of topsoil and soil erosion by water in agricultural areas: A multi-criteria approach for various land use scenarios in the Western Carpathians using a SWAT model. Land Use Policy 73, 363-372.

Helmers, M.J., Isenhart, T.M., Dosskey, M.G., Dabney, S.M., Strock, J.S., (2008). Buffers and vegetative filter strips. UMRSHNC (Upper Mississippi River Sub-Basin Hypoxia Nutrient Committee). Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop. St. ASABE, Joseph, Michigan, pp. 43–58.

Hochbichler, E., Baumgartner, L., Schuster, K., Starlinger, F., Englisch, M., Hagen, R., Wolfslehner, G. (2015). Waldbauliche Empfehlungen für die Waldbewirtschaftung in Niederösterreich. Amt der Niederösterreichischen Landesregierung, Abteilung Forstwirtschaft, St. Pölten, page 203-206.

Iwasaki, K., Shimoda, S., Nakata, Y. Hayamizu, M., Nanko, K., Torita, H. (2024). Remote sensing of soil ridge height to visualize windbreak effectiveness in wind erosion control: A strategy for sustainable agriculture. Computers and Electronics in Agriculture 219, 108778.

Koeck, R., Härtel, E., Holtermann, C., Hochbichler, E., Hager, H. (2002). Soil Moisture Dynamics Related to Vegetation Cover in the Subalpine Zone of the Northeastern Calcareous Alps in Austria. Results of Case Studies in the Rax Area. Centralblatt für das gesamte Forstwesen, 3/4, 297-306

Koeck, R., Hochbichler, E., Holtermann, C., Hager, H. (2014). Soil moisture and soil temperature dynamics at the tree line of Mount Rax, 1999-2010. Austrian Journal of Forest Sciences 2014; 131(1): 45-62.

Kumi, J.A., Kyereh, B., Ansong, M., Asante, W. (2021). Influence of management practices on stand biomass, carbon stocks and soil nutrient variability of teak plantations in a dry semi-deciduous forest in Ghana. Trees, Forests and People 3, 100049.

Li, M., Li, H., Fu, Q., Liu, D., Yu, L., Li, T. (2021). Approach for optimizing the water-land-food-energy nexus in agroforestry systems under climate change. Agricultural Systems, 192, 103201.

Lobell, D.B., Deines, J.M., Tommaso, S.D. (2020). Changes in the drought sensitivity of US maize yields. Nat. Food 1 (11), 729–735.

Loewe-Munoz, V., Delard, C., del Río, R., Barrales, L., Balzarini, M. (2023). Mixed *Castanea sativa* plantations including arboreal companion species enhance chestnut growth and high-quality timber production. Forest Ecology and Management 529, 120742.

Minoche, D., Risio-Allione, L., Herrero De Aza, C., Martínez-Zurimendi, P. (2017). Density management diagram for teak plantations in Tabasco, Mexico. iForest 10: 909-915.

Miyamoto, A., Takamura, G. (2026). Evaluating forest management status across ownership types based on stand structure typology for sustainable use in conifer plantations. Forest Ecology and Management 602, 123414.

Nölte, A., Yousefpour, R., Cifuentes-Jara, M., Piotto, D., Murillo, O., Zúñiga, P, Hanewinkel, M. (2022). Broad-scale and long-term forest growth predictions and management for native, mixed species plantations and teak in Costa Rica and Panama. Forest Ecology and Management 520, 120386.

Nordstrom, K.F., Hotta, S. (2004). Wind erosion from cropland in the USA: a review of problems, solutions and prospects. Geoderma 121, 157–167. https://doi.org/ 10.1016/j.geoderma.2003.11.012.

Österreichische Auenstrategie (2023). Auenstrategie Österreich 2030+. Bundesministerium für Land- und Forstwirtschaft, Regionen und Wasserwirtschaft (historic) – Now: Bundesministerium für Land- und Forstwirtschaft, Klima- und Umweltschutz, Regionen und Wasserwirtschaft. www.bmluk.gv.at (search for „Auenstrategie 2030+).

Pandey, S., Kumar, P., Zlatic, M., Nautiyal, R., Panwar, V.P. (2021). Recent advances in assessment of soil erosion vulnerability in a watershed. International Soil Water Conservation Research 9, 305–318. https://doi.org/10.1016/j.iswcr.2021.03.001

Park, S.W., Mostaghimi, S., Cooke, R.A., McClellan, P.W. (1994). BMP impacts on watershed runoff, sediment, and nutrient yields. JAWRA 30 (6), 1011–1023.

Parsons, J.E., Daniel, R.B., Gilliam, J.W., Dillaha, T.A. (1991). The effect of vegetation filter strips on sediment and nutrient removal from agricultural runoff. Proceedings of Environmentally Sound Agriculture Conference, Orlando, FL, pp. 324–332.

Pollegioni, P., Del Lungo, S., Müller, R., Woeste, K.E., Chiocchini, F., Clark, J., Hemery, G., Mapelli, S., Villani, F., Malvolti, M.E., Mattioni, C. (2020). Biocultural diversity of common walnut (*Juglans regia* L.) and sweet chestnut (*Castanea sativa* Mill.) across Eurasia. Ecology and Evolution 10: 11192–11216.

Reichenberger, S., Su, R., Sittig, S., Multsch, S., Carmona-Cabrero, A., López, J., Muñoz-Carpena, R. (2023). Dynamic prediction of effective runoff sediment particle size for improved assessment of erosion mitigation efficiency with vegetative filter strips. Science of the Total Environment, 857, 159572.

Rosenfield, M.F., Brown, L.M., Anand, M. (2022). Increasing cover of natural areas at smaller scales can improve the provision of biodiversity and ecosystem services in agroecological mosaic landscapes. Journal of Environmental Management 303.

Saklaurs, M., Libiete, Z., Jansons, A., Donis, J., Kitenberga, M., Elferts, D., Jurmalis, E. (2022). Provision of Ecosystem Services in Riparian Hemiboreal Forest Fixed-Width Buffers. Forests 13, 928. https://doi.org/10.3390/f13060928.

Steiner, C., Wirth, J., Lehner, S. (2023). Mehrnutzenhecke – Bodenschutzanlagen in Niederösterreich (Broschüre). Niederösterreichischer Landschaftsfonds - Niederösterreichiche Agrarbezirksbehörde, St. Pölten - pp 25.

Tullus, T, Randlane, T., Saag, A., Lutter, R., Siller, M.L., Soppa, R., Täll, K., Vysotskaa, N., Kaivapalu-Kaasika, M., Ots, K., Tullus, H. (2026). Mature hybrid aspen plantations on former agricultural land can enhance landscape connectivity for forest species. Trees, Forests and People 23, 101161.

Twery, M.J., Hornbeck, J.W., (2001). Incorporating water goals into forest management decisions on a local level. Forest Ecology and Management 143, 87-93.

Wallbrink, P.J., Croke, J., (2002). A combined rainfall simulator and tracer approach to assess the role of Best Management Practices in minimising sediment redistribution and loss in forests after harvesting. Forest Ecology and Management 170, 217 – 232.

Willner, W., Grabherr, G. (2007). Die Wälder und Gebüsche Österreichs. Spektrum Akademischer Verlag, Elsevier München.

WRB (2015). World Reference Base for soil resources 2014, update 2015 - International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.

Zhang, Q., Lu, Z., Ying, J., Qiu, Y., Wang, P., Xu, Z., Xu, D., Li, Y. (2026). Nonstationary agricultural drought risk under compound meteorological drought and hot conditions. Journal of Hydrology 668, 135059.

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