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Climate change mitigation potential of trees in shelter belts of drainage ditches in cropland and grassland

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Latvian State Forest Research Institute SILAVA

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REPORT

Report on “crop communities”, “site types” and management systems suitable for different “site types” in the shelter belt[1]

Salaspils, 2023

1 V01 – after acceptance or improvements suggested by by ERDF experts will be published online with ISSN number, first published online 2023-11-29 on https://www.silava.lv/en/research/active-projects/climate-change-mitigation-potential-of-trees-in-shelter-belts-of-drainage-ditches-in-cropland-and-grassland

Contents

Criteria for selection of trees or shrub species for shelter belts

The different tree species growing along the ditches not only shade the watercourse, absorb the biogenic elements in the runoff water and connect to the atmosphere in the process of photosynthesis. (

Figure 1, Figure 2).

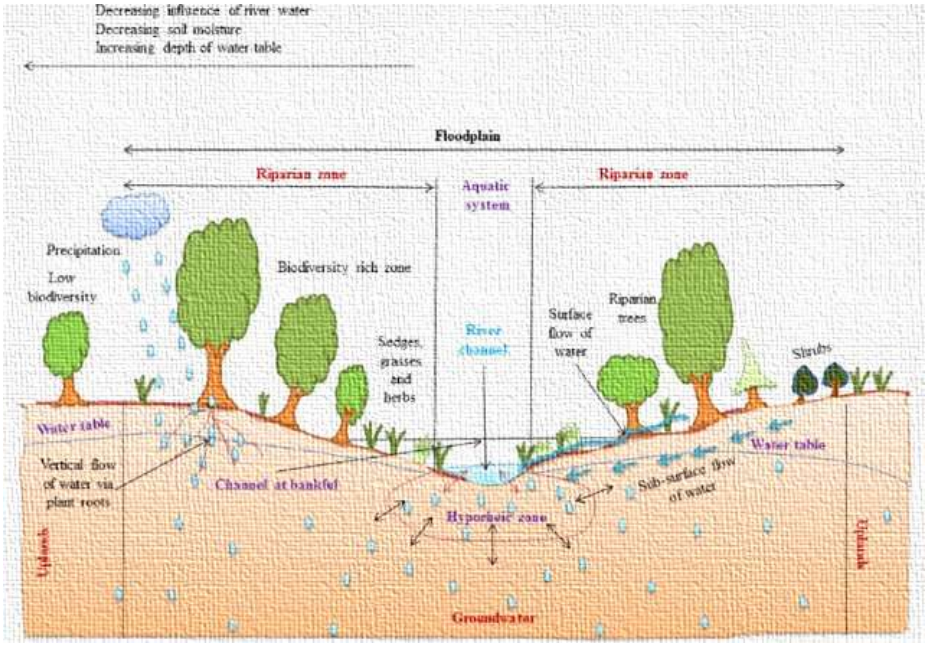


Figure 1 Shelter belts funkcionality aacoding to Singh et al. 2021[2]

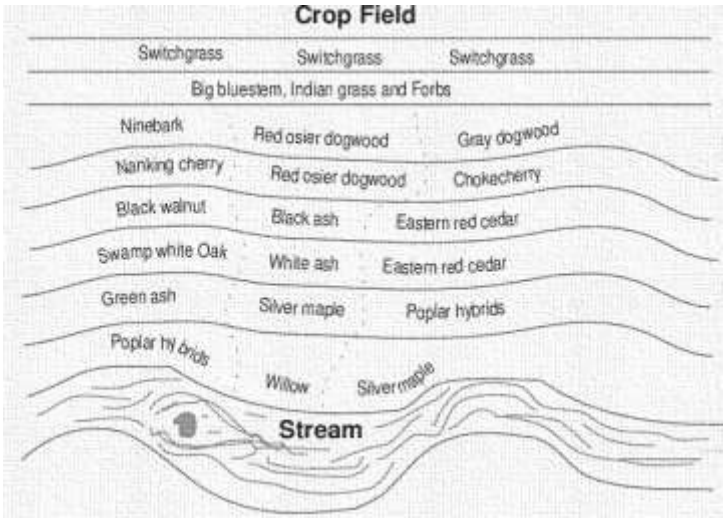


Figure 2 Tree species composition wxamples and streem curve[3]

[2] https://link.springer.com/article/10.1007/s11355-020-00436-5

[3] https://www.semanticscholar.org/paper/Buffer-Strip-Design%2C-Establishment%2C-and-Maintenance-Schultz-Wray/9a3558ee8c88f01f6184de147a871369bca4261d

Fito-retention or fito-accumulation by fast growing biomass crops have been shown to act as a multilevel biological filter (Figure 3).

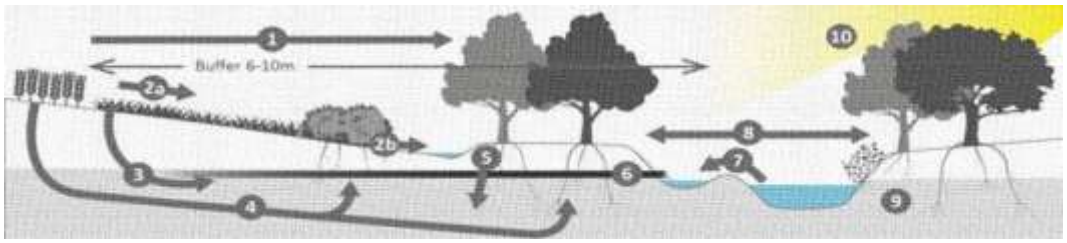
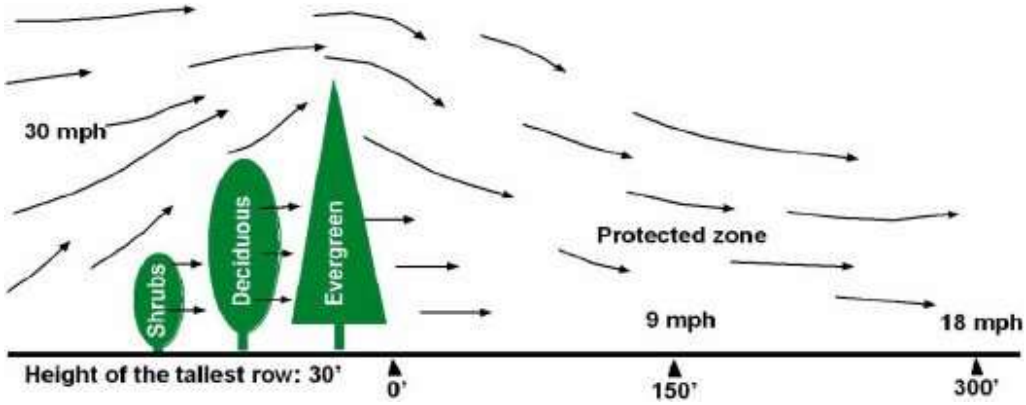


Figure 3 Environment friendly buffer strip element design principles: (1) catchment of agrochemical spray; (2) filtering of runoff, particles (a), water retention (b);(3) undisturbed, improved infiltration part -vertical drainage; (4) Growing vegetation as nutrient uptake and utilization; (5) natural consumption of organic particles by soil biota; (6) natural consumption of biogen elements by plants prevents its pass to the water bodies; (7) profiled banks contribute to additional water retention and sediment accumulation; (8) riparian and aquatic vegetation acts as rough filters and remove pollutants; (9) tree roots fix banks and prevent soil erosion; (10) Shading cools water and reduce thermal stress of aquatic ecosystem (modified E. Hodgson, 2023).

In addition to improving the quality of the environment, rows of trees are important creators of the microclimate, they provide a windbreak (dust collector and noise dampening effect (Figure 4).



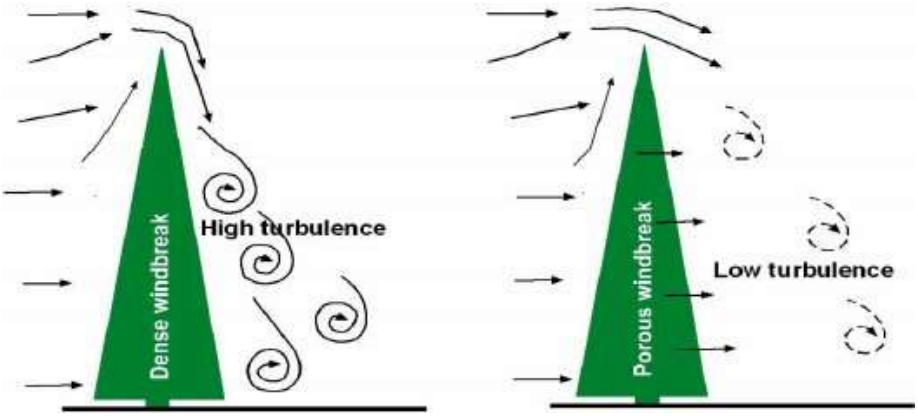


Figure 4 Principle scheme of windbreak strip operation (according to Tamang, uc. 2009)4

In the previous century, the establishment of tree buffer belts along roadside ditches and open drainage systems of agricultural fields was a common practice. Today, road buffer belts are not popular, because roads are built higher than in the past, so that they do not get stacked in snowy winters, but as sound and dust barriers had been form embankments or installed fences.

It is difficult to say why the installation of windbreak strips in agricultural areas has been stopped, perhaps because the open drainage systems have been replaced with a drain network, or because the inclusion of these areas in the area payment schemes was not included for some time.

Species suitable for tree belts

In the fifties of the previous century, recommendations were prepared as to which tree species should be planted in windbreak strips, most of them are fast-growing and also suitable for protecting watercourses against biogenic elements. When assessing the suitability of trees for windbreak strips, Rieksiņš characterizes them as:

- frost tolerance, where 1-completely frost-tolerant, 2 - the tips of annual shoots freeze, 3 - annual shoots freeze, 4 - two-year shoots freeze, 5 - three-year shoots freeze, - 6 - freezes to the level of snow;
- fast growing, where 1 - very fast growing (more than 1 m per year), 2 - fast growing (0.75 - 1 m per year), 3 - moderately fast growing (0.5-075 m per year), 4 - slow growing (no more than 0 .5m per year);
- height to be reached;
- soil suitable for the plant, where m.-clay, sm. sand, m.s.m. – clay sand, sm.m. – loam;
- degree of soil moisture, where s.- dry, v.- valga, m. – humid, sl. – wet soil;
- shade tolerance, where l.e. – very shade-tolerant, e. – shade tolerant, g. - light demanding, l.g. – a very light-demanding species (Table 1).

[4] https://journals.flvc.org/edis/article/view/118158/116112

Table 1 ***Wild growing local and introduced tree species planted in buffer strips and windbreak strips (according to I. Riekstiņš 1959)***[5]

Genus	specie	frost tolerance	growing	height	soil	moisture	shade tolerance
Populus	*trichocarpa*	1	1	25	m. sm.	m.	g.
Tilia	*cordata*	1	4	23	m. sm.	m.	ļ.ē.
Salix	*alba*	1	2	21	m. sm.	m.	g.
	fragilis	1	2	18	m. sm.	m.	g.
	caprea	1	2	15	m. sm.	m.	g.
	daphnoides	1	2	12	m. sm., sm.	s., v., m.	g.
	purpurea	1	2-3	4	m., sm.	m.	e., g.
	viminalis	1	2	5	m., sm..	m.	e., g.
	acutifolia	1	3	8	m. sm., sm.	s., v., m.	g.
	petandra	1	2	7	m. sm.	m.	g.
Alnus	*glutinosa*	1	1-2	20	m. sm.	m., sl.	e., g.
Betula	*pendula/verrucosa*	1	2-3	25	neizvēl.	m.	ļ.g.
	pubescens	1	2-3	25	neizvēl.	m.	ļ.g.
Acer	*platanoides*	1-(5)	4	18	sm. m.	v.	ļ.e.
Quercus	*robur*	1	4-3	25	sm. m.	v., m.	g.
Coryllus	*avellana*	1-4	3-4	4	sm. m.	v., m.	g.
Rosa	*canina*	1-6	3-4	1,5	m. sm., m.	v.	g.
	monogyna	1	3-4	5	sm.m.	v.	g.
Viburnum	*opulus*	1	3-4	3	sm. m.	v.	g.
Picea	*abies/excelsa*	1	3	25	m. sm.	v.	ļ.e.

The criteria for quick supervision and frost tolerance given in the table above can be overestimated, because since the middle of the previous century, Latvia has become warmer climate conditions. In addition to the listed criteria, indicators of GHG capture potential, heat capacity, self-renewal capacity (the branch system must be installed once and then only maintained), plasticity - resistance to extremes - drought and flooding should be added. Using breeding varieties of willows has advantages: firstly, the selected planting material has a higher yield and is adapted to different climatic conditions, secondly, in order to apply for Rural Support Service Republica of Latvia direct payments it is necessary to plant willows of a selected variety (https://likumi.lv/ta/id/341260-tieso-maksajumu-pieskirsanas-kartiba-lauksaimniekiem).

Selected cultivars have been cross-bred for higher yields, steep forms of shrub that facilitate mechanized harvesting, and greater resistance to pests and diseases. Two willow breeding programs are active in Europe, where new, improved varieties are being developed for short-rotation woody crop plantations for biomass production. The Swedish program is controlled by **Svalöf Weibull AB**, whose willow cultivars are based on *Salix viminalis, Salix dasyclados*

[5] Riekstiņš I., Koki un krūmi vējlauzēju stādījumos, LPSRS ZA izdevniecība, Rīga, 103.lpp.

and *Salix schwerinii*. Commercially available, certified varieties of the Swedish program: 'Tora', 'Sven', 'Torhild', 'Tordis', 'Olof', 'Gudrun', 'Inger' and others (Table 1). The second breeding program **IACR-Long Ashton** in the United Kingdom (financed by the European Willow Breeding Partnership), the selected willow varieties are based on *Salix viminalis* and *Salix caprea*, *Salix rehderiana*, *Salix udensis*, *Salix schwerinii*, *Salix discolor* and *Salix Aegyptiaca*. The UK breeding program has produced varieties such as 'Nimrod', 'Resolution', 'Discovery', 'Endeavour', 'Beagle' and 'Terra Nova' (Table 2). Commercial plantations in Latvia have varieties selected in Sweden.

Table 2 The main characteristics of selected willow varieties

Variety	Sex	First-year height after cutback, m	Number of shoots per stool	Mean stem diameter at 1m, cm	Calorific value, MJ kg^{-1}
'Endeavour'	Female	4.0	4 – 8	1.5	18.6
'Gudrun'	Female	2.7	5 – 8	1.6	n.d.
'Inger'	Female	4.2	4 – 8	1.6	16.6
'Jorr'	Male	n.d.	6 – 10	1.2	n.d.
'Olof	Male	4.6	4 – 7	1.5	17.7
'Resolution'	Female	4.6	3-6	1.6	16.8
'Sven'	Male	n.d.	n.d.	n.d.	16.9
'Terra Nova'	Female	3.7	5 – 10	1.4	18.4
'Tora'	Female	4	3 – 6	1.6	16.8
'Tordis'	Female	4	3 – 6	1.6	17.7
'Torhild'	Female	n.d.	3 – 6	n.d.	17.6
'Endurance'	Female	4.3	8 – 9	1.6	18.3

n.d.- not defined Source: modified (Caslin et al., 2012).

Selected varieties are protected by plant breeders' rights, which means that it is illegal to produce propagating material for personal consumption or sale. Certified planting material can be obtained from a specialist grower or licensed supplier. Commercial planting material, one-year-old cuttings are supplied for mechanical planting. Of all Salix which is registered in the FAO list, 33 varieties are suitable for the creation of energy crops for obtaining bioenergy (Kuzovkina, 2015).

In Poland testing 11 different varieties of willows for biomass production, 'Ekotur' and 'Žubr' were recognized as the most suitable, from which obtained the most dry matter (11.5 and 13.8 t ha^{-1} per year). From the willow varieties: 'Tur', 'Sven', 'Olof', 'Torhild', and 'Tordis', a much smaller amount of dry matter was obtained, 7.2 - 8.2 t ha^{-1} per year (Matyka, Radzikowski, 2020).

In Denmark, among eight willow varieties tested, 'Klara', 'Linnea', 'Resolution', 'Stina', 'Terra Nova', 'Tora', 'Tordis', grown in five different locations with different soil characteristics, climatic conditions, and management type, where the willow variety 'Tordis' was recognized as the most productive, which showed the highest dry matter indicators in four different places, where the dry matter mass from these places was obtained from 5.2 to 10.2 t ha^{-1} per year (Larsen et al. , 2014).

The most suitable soil for willow planting is a well-aerated, moisture-retentive, where the soil type is from medium to heavy loam with a minimum cultivation depth of 0.20 – 0.25 cm to allow mechanized planting. On the other hand, a more suitable place for planting woody crop plants is where the amount of precipitation reaches 900-1100 mm per year, or in places where groundwater is available for woody crop plants. Willows can tolerate occasional flooding, but this can affect crops and harvesting (Short Rotation Coppice…, 2015).

Site types in buffer zones around drainage ditches, how to establish and map

Buffer strips around drainage as multipurpose land management elements

Buffer lines/strips should be established as strips of tree, bushes and grasses or other herbaceous perennials placed in a band of different widths, depending of slope or potential pollution along field margins or beside water courses for reducing of soil erosion or ground water pollution from agricultural land. Leaching of fertilisers are reported a main reason of ditches, later ponds, rivers, lakes or seas eutrophication.

These buffer strips can be different types, which then also determine their management technique (*Stutter et al. 2012*). Also buffer strips are important for biodiversity, in these areas can live birds, small animals etc. and can grow different plants (*Kuglerová el. al. 2014*).

The nutrients instead of causing eutrophication will boost the growth of biomass, increasing yields. Faster development of buffer ecosystem in high - promote the functioning of the buffer and reducing pollution of water (*Carstensen et al. 2021*). Carstensen and colleagues designing integrated buffer zones as novel biogen element leaching mitigation designs with addition ditch or pound systems for catchment of elements before water body - aiming to decrease the loading of nitrogen transported by subsurface drainage systems from agricultural fields to streams (Figure 5).

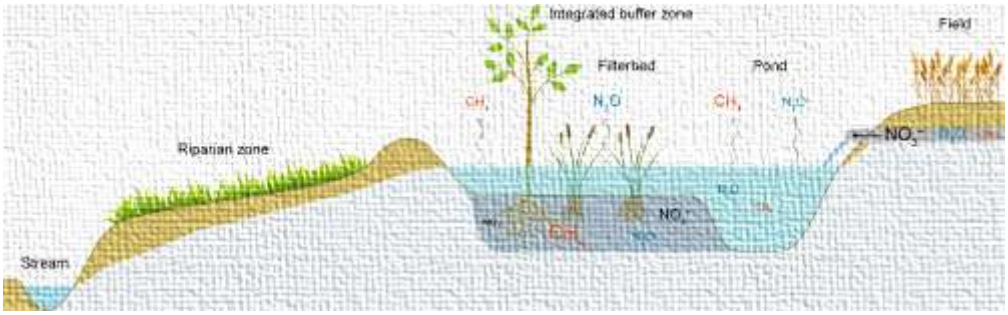


Figure 5 Pond and filterbed, sedimentation, plant uptake of the integrated buffer zones.working princip by Carstensen et al. 2021.

Harvesting biomass should be done regularly in order to help reduce pollutant load, as harvesting means removing of excess nutrients and hazardous elements uptaken by the trees and grasses. Trees, bushes and perennials established in buffer band provide a number of additional benefits to soil health – an increase of biodiversity (*Lorna et al 2020)*. After biomass is harvested this biomass must be removed. This must be done because if this biomass remains in the ground, it leaches more nutrients into the ground and water (*Jabłońska, 2021*).

By planning of undisturbed lines as roads for logistic needs (access for management of strip and operating space for field cop maintenance, as well tree biomass harvesting machinery) also double effect are reached - additional at least 6 m wide plat infiltration area and technical corridor. Integrated buffers also direct and control run-off during heavy precipitation. It is

known that the higher level of engineering means higher establishment costs, but more long-term benefits.

Buffer strips on landscape

The tree and shrub species grown in plantation forests suitable for the establishment of buffer strips can be placed alone or together with perennial grasses in the landscape in different ways. The strips of perennial plantings should be adapted to the topography of the area. Short rotation coppice (SRC) and short rotation forestry (SRF) management system elements and species are preferred to be in use. SRF later on could be used as firewood for farm or even as assortments, if good timber quality received. SRC will go to woody ships for energy or litter, mulch production.

Planting trees in buffer strips capture more C and has a positive impact on the environment, and can provide additional income for farmers by creating buffer strips along the water (*Borin et. al. 2010*). When to buffer strips use plants with high productivity (herbs and grasses), these strips should be harvested and removed once or twice a year to reduce nutrients on ground (*Hille et. al. 2018*).

Low gradient

Flatter areas at the bottom of slopes fits for planting of strips of dense energy biomass crops such as reed canary grass and willow or poplar (SRC) (Figure 6). One of the most sustainable option for the buffer strip is use the hybrid poplar. With such a technique, a large amount of wood and biomass can be obtained in a short period of time, as well as reduce environmental problems that can be caused by agricultural pollution *(Fortier et. al. 2010*).

Figure 6. CRC SRF 20 combinate buffer - where 5-7m wide Populus spp. planted next to Salix spp. or reed canary grass 5-7 m. Between cropland and trees at least 6-meter-wide undisturbed technical corridor (modified E. Hodgson, 2023).

Provided access is unhindered, mechanised harvesting should be possible without impacting functionality of the buffer strip, that strip could be combined with shallow dich before it (Figure 6).

Figure 7 Coppice standards (3m wide zigzag row (with low bush or perennial grass stripe (5-7m), undisturbed technical corridor (~6m) and shallow accumulating ditch (modified E. Hodgson, 2023).

Slopes

Naturally increase flow rate and make harvesting a little bit difficulted.

On medium steep slopes low maintenance crop options, taking in to consideration specific soil conditions and soil bearing capacity, should be considered (Figure 8). Slopes increase the risk of runoff to water, so buffer strips are necessary because they slow down the runoff of nutrients (*Richardson et. al. 2012*).

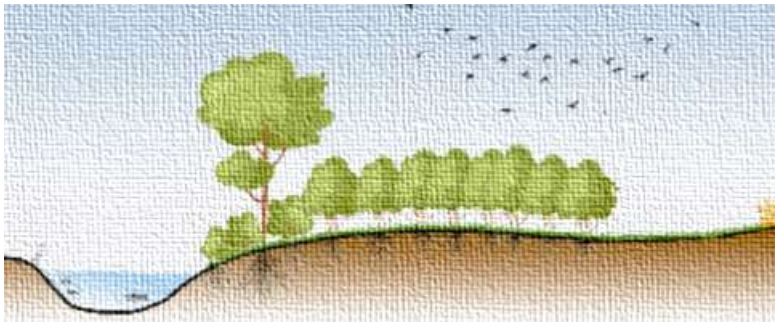


Figure 8 Intermediate gradient -gentle slope vide slope (10-18 m with perennial grasses below different high SFR) and undisturbed technical corridor (modified E. Hodgson, 2023).

When field has minor self-relief, trees bands are less effective, therefore grass strip could be widened, and the species selected could be tough enough for withstanding of higher quantity and velocity run-off flow – that situations are common in silvopasture areas (Figure 9).

Figure 9 Narrow agroforestry buffer (5-6m) as mixed SRF, fencing between trees and farm for stem bark browsing prevention (modified E. Hodgson, 2023).

Steep gradient

Buffers on steep slopes needs to be established predominantly for prevention of erosion and biogen elements run-off. Best solution is rhizome-forming grasses and different layout rooting trees to maximise infiltration and provide deep root structures to stabilise banks (Figure 10).

Figure 10 Extended undisturbed grass- technical corridor strip (10m and more) with different high SRF (~ 6+6 m) (modified E. Hodgson, 2023).

Biomass production is limited to firewood production due to difficulties of harvesting and the requirement of longer rotation lengths, that means that tree species with developed root system and long rotation are suitable for such conditions (Figure 11).

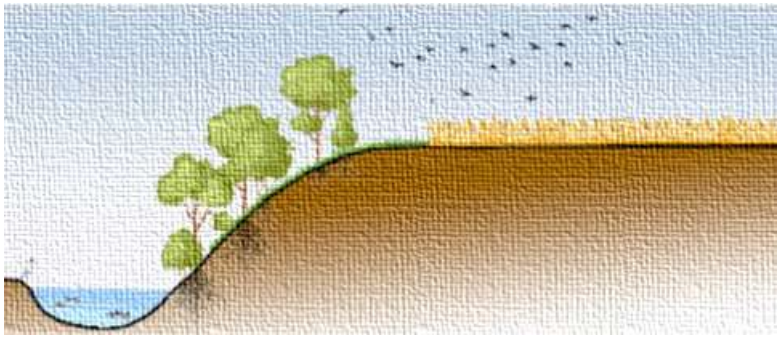


Figure 11 Very steep slope, "run offs washout tolerant" grass stipe (~2m) and mixed tree going to establish "multi-layer roots net" (modified E. Hodgson, 2023).

Conclusions

Remote sensing methods and existing settlements, soil and vegetation maps (LPIS data, Sentinel I and II and LiDAR data, soil and deposition maps) could be used for setting up described above "woody/grass crop communities" on different "site types".. Whole country area could be analysed by usin described abouve approach for species (acoring to ecological functions) and plating design (according to landscape) selection..

Parameters considered include in decision making in the future are soil type (fertility class, texture and moisture regime), exposition and slope, also precipitation and temperature (following to meteorological statistics).

Wet areas with potentially poor soil bearing capacity, as well as water streams will be highlighted as areas, where low impact machinery (with wide tracks) has to be used. Closed drainage systems will be marked using existing maps of drainage systems to adopt planting patterns.

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