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Analysis of economical, social and environmental aspects of agroforestry systems of trees and perennial herbaceous plants

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Abstract. The aim of this study was to determine the economic, social and environmental aspects, that promote choosing an agroforestry system and continuing agricultural production instead of simple afforestation of agricultural land. Material for the study was collected in an experimental demo field located in the central part of Latvia (56°41 N and 25°08 E) established in the spring of 2011, nearby Skrīveri. Two legumes – fodder galega (*Galega orientalis* Lam.) 'Gale', poor-alkoloid lupine (*Lupinus polyphyllus* L.) 'Valfrids' and two perennial grass cultivars – reed canary grass (RCG) (*Phalaris arundinacea* L.) 'Bamse' and festulolium (*x Festulolium pabulare*) 'Felina' were sown between the tree rows and in monoculture on drained mineral soil. Four different fertilisation treatments for herbaceous plants – control (without fertiliser), mineral fertilisers, wastewater sludge and wood ash were used. Biomass, seed yield, agricultural management cost have been investigated since the establishment of experiment in 2011. Potential benefits from growing herbaceous plants for seed, biomass production and possible future income from tree wood and non-wood goods were calculated. Management cost of agroforestry system, plantation forest and traditional sowing were analyzed. The growth of herbaceous plants for seed production together with hybrid aspen in agroforestry system during a 5 year period has a positive balance with all types of fertilisers. The growth of herbaceous plants in a monoculture for biomass production in a 3 year period had a positive balance for all types of organic fertilisations at both cutting frequencies. Positive balance by applying mineral fertiliser was achieved only at two-cut cutting regime.

Key words: agroforestry, fertilisers, hybrid aspen, herbaceous plants, DM yield, seed yield, cash flow.

INTRODUCTION

Agroforestry is a perspective way of biomass production that combines simultaneous growing of woody plants with agricultural crops on the same area for different purposes. Agroforestry is the combination of agricultural and forestry technologies to create integrated, diverse and productive land use system in which two or more plant species interact, one of the species being perennial and having a woody consistency (Somarriba, 1992; Garrett et al., 2000; Dupraz et al., 2005). It is a system of land management that integrates tree and shrub plantings with crops or livestock in order to generate economic, environmental and social benefits. In this era of global warming, fast degradation of land productivity and other environmental hazards, agroforestry is indeed a stake for natural resources and socio-economic sustainability (Gangadharappa et al., 2003). Agroforestry, like multifunctional agriculture, has the objective of promoting economically, socially, and environmentally sustainable rural development (Leakey, 2012). Agroforestry provides opportunities to increase the value of total production through marketing of multiple products from a given unit of land (Feldhake et al., 2008).

Agroforestry practices offer many advantages such as crop and livestock protection, soil and stream conservation and protection, diversification of agricultural revenues through the production of timber and non-timber forest products, promotion of biodiversity, landscape enhancement and carbon sequestration (Cole, 2010). Also, these practices are believed to reduce nonpoint source pollution from row-crop areas by improving hydraulic properties of soil and reducing surface runoff (Paudel et al., 2011).

The main productive advantages of agroforestry systems are linked to better use of resources in a spatial and temporal scale and smaller competition of plants for nutrients. In this system, the woody plants are less influenced by lasting periods of drought, and a stable annual increase in biomass is ensured (Bardule et al., 2013).

Agroforestry adds plant and animal biodiversity to landscapes that might otherwise contain only monocultures of agricultural crops (Noble & Dirzo, 1997; Guo, 2000). Mixing tree species, allowing for small clearings and water catchments in planting, and incorporating understory vegetation can greatly improve habitat for many animals and create micro-site conditions for plant species (Spies & Franklin, 1996).

Design and evaluation of agroforestry systems requires thorough knowledge of relationships between agriculture and forestry. Complementary and supplementary relationships mainly resulting from biological factors make agroforestry an efficient system of land use (Filius, 1982). Agroforestry can be an appropriate technology in areas with fragile ecosystems and subsistence farming.

The advantages of agroforestry systems can confer important social benefits at a farm level, in the different biogeographic regions of Europe and at the same time benefit the general public (Rigueiro-Rodriguez et al, 2008). Farmers in Mediterranean areas felt that the principal benefit of silvoarable systems would be increased farm profitability (37%), whereas farmers in Northern Europe placed greatest value on environmental benefits (28%) (Graves et al., 2008).

One of most promising in term of fast growing tree species in nordic conditions is aspen. While in Southern countries eucaliptus are growed under agroforestry system in Baltic states alternative use of abandoned agricultural areas in Latvia is hybrid aspen (*Populus tremula* L. x *P. tremuloides* Michx.) plantation establishment. Hybrid aspen has high growth potential in Baltic region (Tullus et al., 2012). First breeding plantation of hybrid aspen in Latvia were established in 1960th (Smilga, 1968). Hybrid aspen seams very promising, because in first research plantation is acquired data, that volume increment can reach up to 20m^3 ha^{-1} yr^{-1} in plantation lifespan of 25 years (Tullus et al, 2012a). The highest growth of hybrid aspen plantations of 25 years lifespan can reach 300 m^3 ha^{-1}, the wood is white, with low number of branches which makes the plantation establishment attractive to forest owners (Pavlovics et al., 2010). Aspen wood is suitable for producing light, dense, smooth and non-transparent paper (Treimanis, 2008). In short-rotation plantation forestry harvest times usually correspond with time, when the mean annual increment is the highest, because of the economic profitability of the plantation (Tullus et al., 2012b). For reaching of larger dimensions and saving on planting material costs, lover planting density are recomended. According to Latviana regulation, should be planted at least 800 trees per ha, what alows to combine growing of trees with 'tadicioanal agriculture' between rows.

Agroforestry has the ability to provide short-term economic benefits while the farmer waits for traditional longer-term forestry products. An example of an agroforestry system is a riparian buffer planting that can attenuate flooding effects and protect water quality, while providing wildlife habitat, recreational opportunities and harvestable products, for example, biomass and seed yield of herbaceous plants.

The perennial cropping in the agroforestry system is more successfully used in practical terms; not only it reduces costs, but also facilitates the maintenance of the area in the technical sense, because subsequent tillage between the trees can be problematic.

Economics is concerned with the analysis of choice and decisions: which goods are produced with which resources, and how much of these resources may be used in order to achieve certain objectives. Economic studies of agroforestry systems have shown that financial benefits are a consequence of increasing the diversity and productivity of the systems which are influenced by market and price fluctuations of timber, livestock and crops (Benjamin et al., 2000).

There are no economic studies of agroforestry systems in Latvia. Economic evaluation of grassland sward production has shown the necessity of long – persisting plant use. Production costs of a unit of grass dry matter can be decreased by prolongation of a sward use, and it was stated by significant correlation ($R^2 = 0.95$). Significant relationship between the swards – longevity and swards – establishment and management costs ($R^2 = 0.93$) was established.

Fodder galega and other longest-persisting grasses are good for such purpose (Kirila et al., 2002). In case of two perennial ryegrass seed production years, constant costs (expenses used for establishing sward) decreased twice, in general, lowering total costs. Consequently, from the economic point of view, two production years of perennial ryegrass seeds are profitable – irrespective of somewhat lower seed yield, a certain decrease in expenses was achieved, when seed fields were established and generally higher gross income was obtained (Būmane, 2009).

The successful development of herbaceous plants between trees rows depends on identifying species which are well adapted to low – input biomass production with high yield potential. Reed canary grass, festulolium, and galega are well known in Baltic countries as long-persisting, productive grasses and legume suitable for biogas or fuel pellet production (Tilvikiene et al., 2010; Adamovics et al., 2011). The perennial lupine has a highly developed root system, it grows well in sandy soil and is well adapted to low fertilisation input (Dubrovskis et al., 2011). The above-mentioned species of herbaceous plants grow very well in cool temperate climate. They have good winter hardiness and they survive well in conditions present in Latvia. It is also an important factor that a successful seed production for further varieties propagation is possible. Seed production sowings of perennial herbaceous plants together with woody plants can be a successful decision for financial benefits by decreased production costs and multiple products from a given unit of land.

This paper on economic, environmental and social aspects of agroforestry estimates factors influencing the choice of combination of agriculture and forestry compares the financial flows of agro-forestry systems with the prospect to earn an income from afforestation and distribution of production from agroforestry.

MATERIALS AND METHODS

Study site

The data for this research was collected from demonstration field trials located in the central part of Latvia (56°41 N and 25°08 E) nearby Skrīveri. Study site was established in the spring of 2011 on drained mineral soil. Soil type is classified as a *Phaeozems/ Stagnosols* with a dominant loam (at 0–20 cm depth) and sandy loam (at 20–80 cm depth) soil texture. The content of carbon (C) in soil arable layer – 23 g kg^{-1}, pH KCl – 6.1, plant available phosphorus (P_2O_5) – 277.1 mg kg^{-1}, potassium (K_2O) – 136.8 mg kg^{-1}.

Meteorological conditions during the trial years were different. Year 2012 was characterized by rich precipitation, the annual rainfall was 928 mm (it is 139% of its long-term average rate in Latvia). Precipitation during the vegetation period in 2013 was slightly lower in the long-term average and its distribution was not favourable for grass growth – hot and dry periods were interrupted by short, heavy rainfalls. Lack of moisture in July and August had a negative impact on the development of plants. Precipitation distribution for vegetation period in two trial years is shown in Fig. 1.

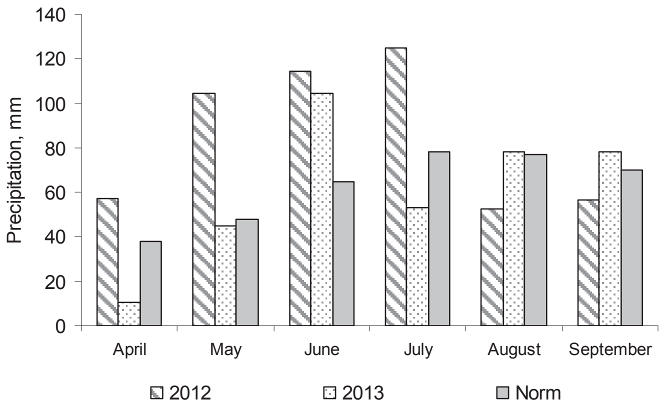

Figure 1. Precipitation during vegetation periods (2012–2013) compared with meteorological norm (Skriveri meteorological station data).

Design and planting material

Two different clones (4 and 28) of hybrid aspen (*Populus tremuloides x Populus tremula*) were planted in the agroforestry system, the planting material originated from JSC 'Latvijas valsts meži', Latvia. The average spacing between trees was 2.5 x 5.0 m and the planting density – 850 trees per ha.

Two perennial legumes – fodder galega (*Galega orientalis* Lam.) 'Gale', poor-alkoloid lupine (*Lupinus polyphyllus* L.) 'Valfrids' and two perennial grass cultivars - reed canary grass (RCG) (*Phalaris arundinacea* L.) 'Bamse' and festulolium (*x Festulolium pabulare*) 'Felina' were sown between the tree rows and in monoculture.

Perennial grasses and legumes for seed production were sown in 2.5 m wide strips between six trees rows, and the size of one plot was 60 m^2. Between the trees and grass lines an empty space of 1.25 m was provided. Thereby swards used for seed production cover half of planted area in this block. Monocultures of herbaceous plants (without woody plants) were sowed in a separate block for biomass production with a 20 m^2 harvest recorded plot size.

Seed production sowings between trees were carried out in mid – June of 2011, biomass production sowings in monoculture were sown in mid – July of 2011 in four replications, using the seeders 'Nordsten NS-1025'. Grasses and legumes were sown without a cover crop using a narrow row spacing for all species in the grass monoculture trials for biomass production and for RCG and festulolium in seed production trials between trees, and broad row spacing (36 cm) for galega and lupine in seed production sowings between the trees.

Seeding rates: galega 12 and 30 kg ha^{-1}; lupine 30 and 60 kg ha^{-1}; reed canary grass 10 and 15 kg ha^{-1} and festulolium 12 and 12 kg ha^{-1} germinating seeds for seeds and biomass production respectively. Legume seeds were treated with nodule bacteria preparations before sowing, wet nitragin grown on agar was used for galega, peat powder mixed with nitragin – for lupine. The plantation was fenced in the autumn of 2012.

Treatments

Four replications of three different fertilisation subplots – control (no fertilisation), wastewater sludge and wood ash, the size of each – 30 x 24 m, were established in the combined woody – herbaceous plantation in the spring of 2011. I class (according to regulations of the Cabinet of Ministers of the Republic of Latvia No. 362) wastewater sludge (dose 10 t_{DM} ha^{-1}) from Ltd. 'Aizkraukles ūdens' (*Aizkraukle Water*) and stabilized wood ash from the boiler house in Sigulda (dose 6 t_{DM} ha^{-1}) were spread mechanically before the planting of hybrid aspen and sowing of legumes and perennial grasses (Table 1). Heavy metals target values and precautionary limits are not exceeded in fertilised soils according to legislative regulation for soil and ground quality (regulations of the Cabinet of Ministers of the Republic of Latvia No. 804). For comparative evaluation of grasses and legume seed yields along with the mentioned fertilisers there was also a mineral fertiliser option included: N25:P50:K125 for the legumes and N60:P50:K125 for the grasses. In the block of herbaceous plants grown in monoculture for biomass production in addition to the above mentioned fertilisation variants the digestate from Training and Research Farm 'Vecauce' was included, treatment dose 30 t ha^{-1}.

Table 1. Chemical composition (content of elements, g kg^{-1}) of fertilisers

Fertiliser	N	P	K	Ca	Mg	Mn	Fe	Na
Wood ash	0.40	10.9	31.6	224.8	30.9	3.1	4.6	1.6
Wastewater sludge	25.9	16.3	2.2	10.9	11.3	0.3	23.4	0.2
Digestate (g L^{-1})	2.1	0.4	3.3	0.10	0.35	0.01	0.05	0.29

In the control fields, no fertilisation was used, the fertilisation with sewage sludge and ash was done once as initial – in the establishment year, the fertilisation with mineral fertiliser was done every year, total 6 times.

Measurements and statistical analysis

Biomass, seed yield, agricultural management cost were investigated since establishment of experiment in 2011. Herbaceous plants seeds were collected by using a small experimental harvesting *Wintersteiger* and seed yield was determined. Herbage biomass dry matter was recorded using two cutting frequencies – 2 cuts per vegetation period and 1 late cut in October.

For the estimation of economical efficiency of perennial grasses and legumes biomass and seed production between the tree rows and in monoculture, the production costs and income calculations have been done. In the economic model all prices, technologies and growing condition were based on Latvia's conditions. Equipment transportation to the plantation and transportation of the end product to the customer is considered to be 20 km. The establishment and management costs of field trial agroforestry plantation in Skriveri were taken into account. Potential benefits from growing of herbaceous plants for seed, biomass production and possible future income from trees wood and non-wood goods were calculated. Economical calculations according to plantation life-cycle starts with the establishment costs, which includes ploughing, trenching and cultivation, also glyphosate type herbicides were used to reduce weed impact. Sowing and cutting costs are the same for all plant species, seeding rates are different for every specie in every type of management. All prices were taken from The Latvian Rural Advisory and Training Centre review 'Technical service prices in Latvia, 2013' (Tehnisko pakalpojumu cenas ...).

Income was calculated for obtained biomass dry matter yield and seed yield based on average hay, bale silage and seed production prices in Latvia in 2013. For herbage monoculture fields calculations were done for a 3 year (2011–2013) period – sowing year, first and second sward production years where biomass is used for biogas production at a frequent cutting regime, and for grass pellets production for heating at an extensive cutting regime. Income from seed production sowings between trees was calculated for 5 production year period, based on two harvest year average seed yields.

The experimental data of perennial grasses and legumes biomass and seed yield were statistically analyzed by applying the analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Sowing (plantation establishment) year

Perennial grasses and legume provide full herbage yield in the first production year or the next year after sward establishment. Dry matter (DM) yield in the year of establishment could reach about 5 t ha^{-1} depending on sowing time and meteorological conditions. Our trial with a late sowing time (middle of July) and unfavourable weather conditions caused lower average DM yields –1.89 to 3.30 t ha^{-1} depending on species. Dry and warm weather in July and August had a negative impact on plant growth and utilization of applied fertiliser. Applying sewage sludge and digestate provided significant increase of mean DM yield in the sowing year. The influence of wood ash and mineral fertiliser was not significant.

The first production year of dry matter

Sowings of perennial lupine did not establish well in the first year, the plants were weak and there were quite few generative sprouts. Very poor vegetation was the cause why lupine was excluded from trials and its DM and seed yield has not been evaluated.

In the first production year the average grasses and legume dry matter yields were estimated as satisfactory (6.76 t ha^{-1}). Grasses and legume dry matter yields were dependent on the applied fertiliser type and grass species and cutting frequency (Fig. 2.). Each of the applied fertiliser provided significant increase of mean DM yield for investigated species in comparison with control (5.68 t ha^{-1}). The highest RCG and festulolium DM yield were achieved by using mineral fertiliser on average for both cutting frequencies (9.11 and 9.74 t ha^{-1} respectively). An essential DM yield increase was provided by 38% applying wastewater sludge. Digestate treatment provided significant RCG and galega DM yield increase (on average 1.45 t ha^{-1}).

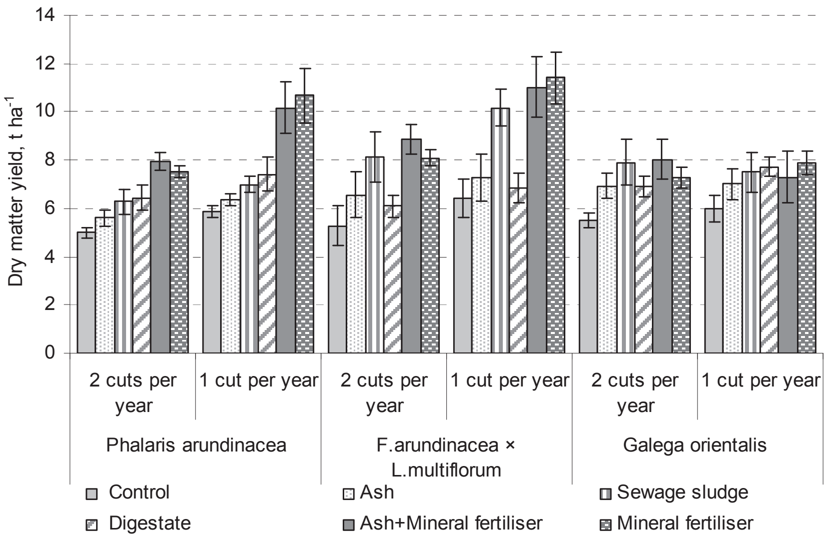

Figure 2. The DM yield of herbaceous plants in the first year of sward use, t ha^{-1}; error bars indicate standard errors.

The highest average DM yield (8.00 t ha^{-1}) was achieved with cutting once in a season – at a crop senescence in comparison with a two – cutting frequency (6.91 t ha^{-1}). The effect of fertilisation was expressed better by applying one cut in a season – the average increase of DM yield was 2.43 t ha^{-1}, in comparison with the average DM yield increase (1.95 t ha^{-1}) at two-cutting regime.

The second production year of dry matter

In the second production year average grasses and legume dry matter yields were estimated as moderate (5.48 t ha^{-1}). The lowest yield in the second year can be explained by meteorological conditions – very late spring and an insufficient amount of precipitation and unfavourable distribution of rainfall in summer.

In the second production year the similar effect of fertilisation was observed on grasses and legume dry matter yields. The highest RCG and festulolium DM yields were achieved by using mineral fertiliser on average for both cutting frequencies (9.50 and 7.09 t ha^{-1} respectively). Sewage sludge and digestate application had positive effect on DM yield production (Fig. 3.). The applying of wood ash did not provide significant DM increase for both intensities of management. It can be explained by meteorological conditions – dry and hot weather during the summer.

The highest average DM yield was given by reed canary grass at the management with one late cut. The average festulolium DM yields did not differ significantly between two cutting regimes. The highest average DM yield at a frequent cutting regime was given by galega, as nitrogen fixing papilionaceous plant with highly developed root system that reaches deep into the soil and good regrowth after cuts. By mowing galega once per season in autumn relatively low DM yield was obtained, which can be explained by partial plant defoliation.

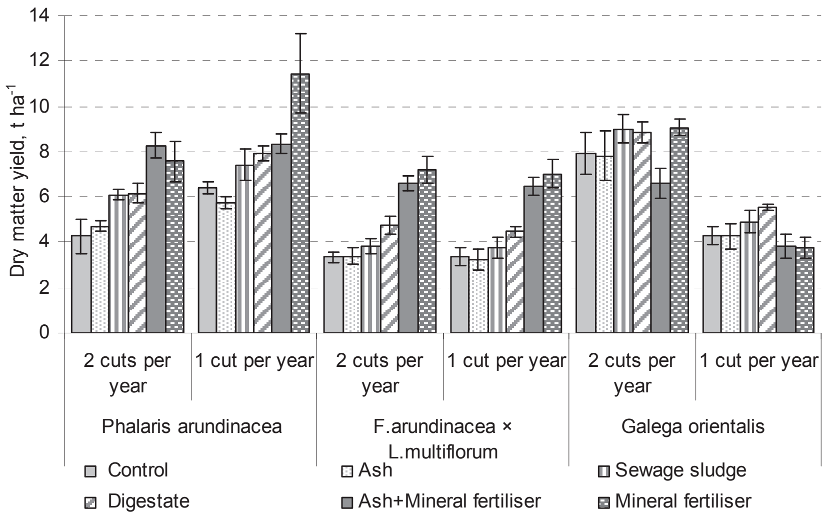

Figure 3. The DM yield of herbaceous plants in the second year of sward use, t ha^{-1}; error bars indicate standard errors.

Seed yields

The average seed yields of the herbaceous plants species obtained in the first year of use are estimated as good for festulolium and moderate for reed canary grass and galega. Seed yield formation was influenced by plant biological traits and meteorological conditions.

Fodder galega has very slow development in the sowing year and in the first year of use (Parol & Viiralt, 2001). The seed production of forage legumes including galega are very unstable. The most important factor for legumes forming seed are the weather conditions, therefore seed yield varies by year, depending on weather conditions at the time of flowering and harvesting (Meripold, 2005). Numerous rainy days during the vegetation period in 1st year of use did not allow the pollination of galega flowers and made a negative effect on the seed yield, therefore the obtained galega seed yields were quite poor.

The results of the first production year indicate that in general the use of fertilisers in the plantation facilitated higher yields of seeds. An essential increase of seed yield for all grass species was provided by applying wastewater sludge (Table 3). The highest increase of seed yield by applying the sludge was observed for RCG (175 kg ha^{-1} or 136% more in comparison with control variant). The increase of festulolium seed yield was 275 kg ha^{-1} or 23%, but for galega it was respectively 134 kg ha^{-1} or 95% more in comparison with the control. The greatest increase of seed yield (363 kg ha^{-1} or 31%) for the quick-growing festulolium was provided by the use of mineral fertilisers. As to galega being a nitrogen fixing papilionaceous plant the greatest increase of seed yield (230 kg ha^{-1} or 163%) was provided by the use of ash.

Table 2. The seed yield of perennial grasses in 1st and 2nd year of use (2012–2013) in agroforestry system, kg ha^{-1}

Fertiliser	Reed canary grass		Festulolium		Galega	
	1st year of use	2nd year of use	1st year of use	2nd year of use	1st year of use	2nd year of use
Control	129	197	1,176	202	142	427
Mineral fertiliser	225	436	1,539	278	185	535
Sewage sludge	304	373	1,451	191	276	444
Ash	241	282	1,296	220	372	568
Mean	225	322	1,365	223	244	493
$LSD_{0.05}$	153.2	220.0	253.5	54.3	123.1	128.3

In the 2nd production year seed yields of RCG and galega were estimated as being good. It is characteristic for both species to give the full seed yield in the second production year. Festulolium seed yield in the second production year was considerably lower. Low seed yield was caused by big aftermath length after seed harvest in previous year. The grate aftermath did not affect RCG and galega development in spring, but festulolium had later spring regrowth and plants were weak.

The results of the second production year indicate that in general the use of fertilisers in the plantation facilitated higher yields of seeds.

Economic evaluation

The combined cultivation of trees and grasses on the same area give possibility to save costs and earn an incomes in first years, which cover starting expenses. The soil preparation, herbicide use, land taxes and administration costs are the same for both systems, so growing these species in agroforestry system gives chance to consolidate them.

First incomes from hybrid aspen plantation, if they are growing for log production, will be in the plantation 20th year from thinning and the second incomes in the final felling at the plantation age of 40 years. Hybrid aspen growing together with perennial herbaceous will give first incomes in the first year of plantation, which gives possibility to cover establishment costs, planting material, planting and tending costs after 3–5 years from plantation foundation. The perennial herbaceous in agroforestry system usually grows 4–5 years. After 5 years, to keep seed yields high, is necessary to parse the plantation. In first 5 years the trees remains higher dimensions, so later it's hard to do trashing, seed collection and fertilisation. That's why perennial herbaceous grows in agroforestry system usually for first 4–6 years.

The growth of herbaceous plants for seed production in agroforestry system during a 5 year cycle has a positive balance with all types of fertilisers. The most beneficial for the reed canary grass under the specific conditions was ash fertiliser, it provided the highest profit – on average 610 EUR ha^{-1} a year, sludge fertiliser had a slightly lower profit – on average 566 EUR ha^{-1} a year. The results for galega were similar to RCG, ash and sludge fertilisers provided almost the same profit – 533 and 537 EUR ha^{-1}.

The best results for festulolium obtained by using of sewage sludge (455 EUR ha^{-1}) and ash (416 EUR ha^{-1}).

Average site preparation costs in establishment year in all plantation models are 101 EUR ha^{-1}. Hybrid aspen establishment costs in all plantation models first year are 899 EUR ha^{-1}, the main costs are for planting stocks, planting and defensive remedies. In the latest years costs for hybrid aspen are insignificant, which mainly consists of agro – technical care and defensive remedies.

For the perennial herbaceous crops establishment costs, seeding, cutting, trashing, seed drying, transport costs, land taxes and grants are the same for all crops. Although seed cleaning, seed prices and seeding rates vary in different species. Also fertilisation costs are different for every fertiliser.

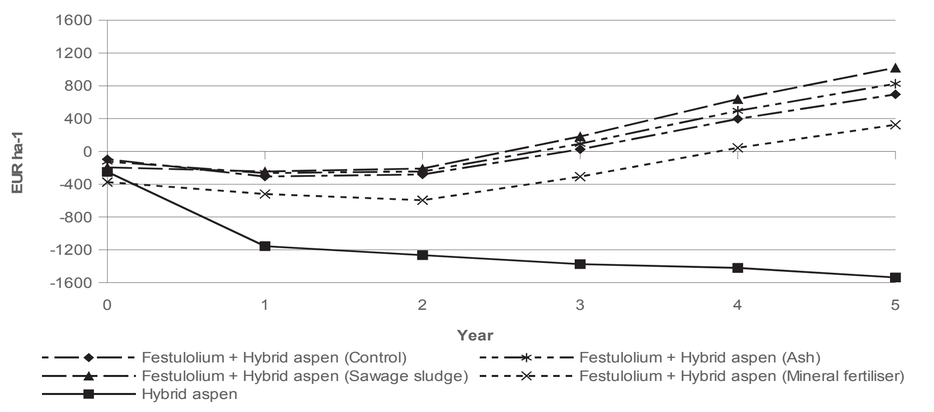

Figure 4. Accumulated cash flow of hybrid aspen and festulolium agroforestry plantation with different fertilisation.

In model, where festulolium and hybrid aspen are grown together, the best results shows fertilisation with sewage sludge, where accumulated cash flow after 5 years is 1,021 EUR ha^{-1}, positive cash flow is achieved after 1st year, mainly because of the high yield in first year. The worst results shows fertilisation with mineral fertiliser 325 EUR ha^{-1}, because of the high mineral prices and fertilisation every year, which gives extra expenses (Fig. 4).

In model, where galega and hybrid aspen are grown together, best results shows fertilisation with sewage sludge, where accumulated cash flow after 5 years is 1, 432 EUR ha^{-1}, positive cash flow is achieved after 3rd year. The worst results shows fertilisation with mineral fertiliser 105 EUR ha^{-1}, (Fig. 5).

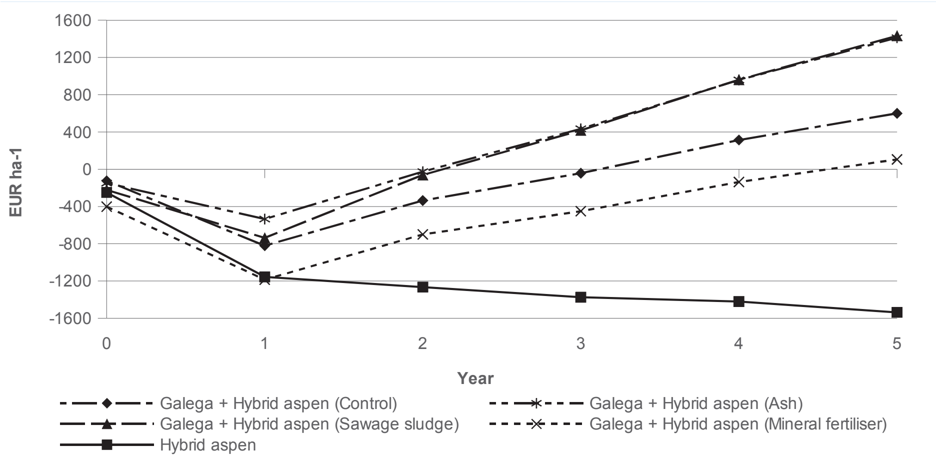

Figure 5. Accumulated cash flow of hybrid aspen and galega agroforestry plantation with different fertilisation.

Galega is one of the longest-persisting plants in swards, notable for a high productivity without mineral fertilisation (Virkajarvi & Varis, 1991), so this time use of fertilisers in galega swards was not economically substantiated.

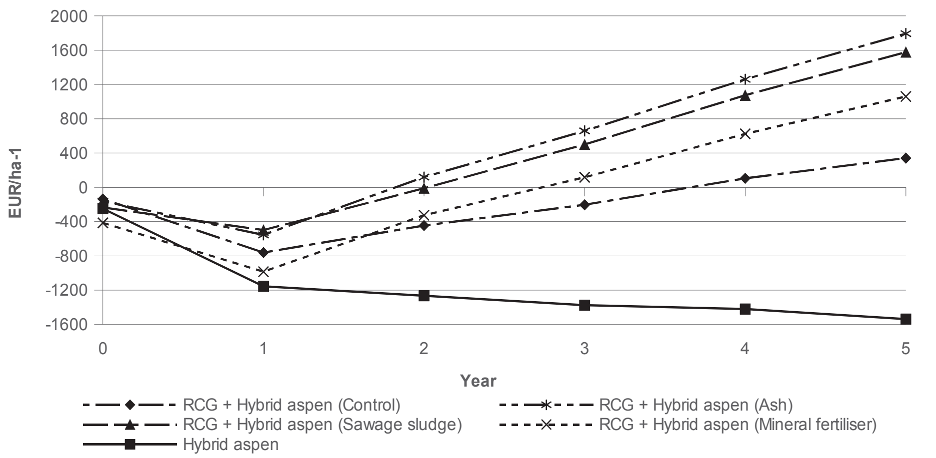

Figure 6. Accumulated cash flow of hybrid aspen and reed canary grass (RCG) agroforestry plantation with different fertilisation.

In model, where reed canary grass and hybrid aspen are grown together, best results shows fertilisation with ash, where accumulated cash flow after 5 years is 1,793 EUR ha^{-1}, positive cash flow is achieved after 2nd year. The worst results shows in control 341 EUR ha^{-1}, (Fig. 6).

In situation where hybrid aspen is grown alone, the accumulates cash flow in year 5th is 1,537 EUR ha^{-1}. The negative cash flow will be till year 20th, when the first incomes from thinning will come.

After comparing the calculated balance for each fertiliser variant we observed that the use of wastewater sludge and digestate as fertilisers for herbaceous plants provided the highest profit (Table 3).

Table 3. The average revenues per year for herbaceous plants sowings in monoculture in 3 year cycle management, by 1 time grass harvest and at frequent cutting regime system per year (2012–2013), EUR ha^{-1}

Fertiliser	Reed canary grass		Festulolium		Galega	
	1 cut per year	2 cuts per year	1 cut per year	2 cuts per year	1 cut per year	2 cuts per year
Control	119	158	67	116	40	211
Ash	85	177	98	136	28	221
Sew.sludge	112	177	126	216	60	300
Digestate	109	199	151	128	30	231
Mineral fert.	-46	23	-97	27	-213	17
Mean	83	147	69	125	-11	196

The growth of herbaceous plants in a monoculture for biomass production in a 3 year period had a positive balance in practically all variants, except for the mineral fertiliser variant – by mowing herbaceous plants once per season for production of burning fuel did not develop a positive balance. Growing galega for biogas production provided the highest profit (on average 196 EUR ha^{-1} per year), it was slightly lower for reed canary grass (on average 147 EUR ha^{-1} per year).

After analysing the results of our study, we can discuss general tendencies providing evidence for the fact that the use of mineral fertilisers, which ensure bigger growth of yields, not always is economically justified. Furthermore, the use of other fertilisers, in our case it was wood-ash, which does not ensure a noticeable growth in dry matter yield, turned out to be economically justified for fertilisation of seed sowings, as the plants need to be provided with different food elements (K, P, Ca, Mg, microelements), unlike it is with biomass production.

CONCLUSIONS

The combined growing of trees and grasses on the same area, give possibility to save costs and earn an incomes in first years, which cover starting expenses.

Reed canary grass, festulolium, and galega could be successfully grown for biomass and seed production between trees rows in the agroforestry system in Latvia. The use of different bio-energy and municipal waste products as fertilisers in general provided higher biomass and seed yields.

The growth of herbaceous plants for seed production together with hybrid aspen in agroforestry system during a 5 year period has a positive balance with all types of fertilisers. Festulolium and galega the best cash flow results shows with sewage sludge fertilisation, reed canary grass with ash fertilisation.

The growth of herbaceous plants in a monoculture for biomass production in a 3 year period had a positive balance for all types of organic fertilisations at both cutting frequencies. Positive balance by applying mineral fertiliser was achieved only at two – cutting regime.

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