CONTRIBUTION OF AFFORESTATION TO SUSTAINABLE LAND MANAGEMENT IN UKRAINE

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Land Use and Water Management in a Sustainable Network Society

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Abstract

This paper addresses the economics of planting trees on bare and marginal agricultural lands for two purposes: timber production and preventing soil erosion. The idea of afforestating[1] rural areas is put forward and assessed across forestry zones in Ukraine, with a comparison of costs and benefits from woodlands. A second basic element is the relation between area shares of woodland and the level of erosion. By using a simulation technique and employing cost-benefit analysis and linear programming, the paper reveals that the establishment of forest plantations to increase timber supply and alleviate soil erosion is economically and environmentally justified for some forestry zones. The paper provides innovative perspectives on the role of afforestation in Ukraine.

Key words: land use, afforestation, erosion, multiple forest benefits, cost-benefit analysis, modelling, Ukraine

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[1] Afforestation is – according to one definition - an expansion of forest area on lands which more then 50 years ago contained forest but later have been converted to some other use. Reforestation is a restoration of degraded or recently (20-50 years ago) deforested lands (IBN-DLO, 1999). In this paper these terms are considered jointly because the time division is rather arbitrary.

Introduction

The traditional concept in forestry is nowadays widened to sustainable forest management incorporating for multiple benefits. Afforestation of marginal land is seen as a long-term means to raise timber production and enhance multi-functional role of forest. This multiple role of forest includes climate change mitigation, the expansion of recreational use and enhancing all environmental forest functions (including erosion prevention), which are concurrently considered to be economic functions (Pearce, *et al*., 1999).

In view of the environmental situation in Ukraine, of which 15 % lies in the zone of an extreme environmental pressure (MEP, 1993), and taking into account the role that forests play for the environment, afforestation is important for a sustainable development. If the social value (Perman *et al.*, 1999, p.251) of wooded land is higher than the social value of this land when used for other purposes, afforestation is reasonable. Financial returns, therefore, from forest management are to be adjusted to shadow values to reflect the true opportunity costs of the forest resources and to account for environmental and social externalities.

Afforestation is proposed as a policy measure to contribute to sustainability in Ukraine's forestry. We define the objectives of the expansion of forest cover, assess afforestation potential and estimate its costs and benefits. An initial cost-benefit analysis (CBA) of the establishment of forest plantations, with an LP model that serves a basis for policy analysis, is elaborated As to address all gains from afforestation is hardly possible in one paper, its scope is limited to timber supply and soil protection benefits from forest.[2] We provide empirical evidence that a low share of forest cover is among the causes of erosion in Ukraine and that planting trees is a sound policy measure to alleviate the erosion. Evaluation of soil protection role of forest is a complement to an initial assessment of timber supply benefits from the newly established forest plantations. If afforestation adds to the welfare of society, its implementation is reasonable. The conclusions ensue.

Afforestation as Resource Management for Sustainability

Despite afforestation is a traditional policy measure, which is considered in the National Program on Land Protection for 1997-2010 (MEP, 1998) and in the State Program "Forests of Ukraine on 2002-2015" (EFI, 2003), tree-planting activities in Ukraine have been shrinking. In addition to the limits of available land, this is caused by difficulties of the transition, which include institutional weakness; an absence of well-defined and ensured system of property

[2] Economics of planting trees in Ukraine to sequester carbon is considered in Nijnik (2005), and the economic component of sustainability in forestry (timber production) is discussed in Nijnik (2004).

rights on land; a shortage of investment and of economic incentives for tree-planting activities; with a shift of forest policy actors' mentality to short-term problems, e.g. rent-seeking, in conditions of high interest rates, etc. However, afforestation is on the agenda in forest policy and practice in Ukraine to enhance a long list of forest functions, with the enlargement of timber supply and the protection of land against erosion, as the priorities.

In conditions of a sparsely wooded territory and an extensive agriculture, with the high level of cultivation (54.8%), Ukraine is faced with erosion on 35% of its arable lands (NAS, 1999). About 20 Mha of land is under various stages of erosion, and it is expanding with time (Figure 1).

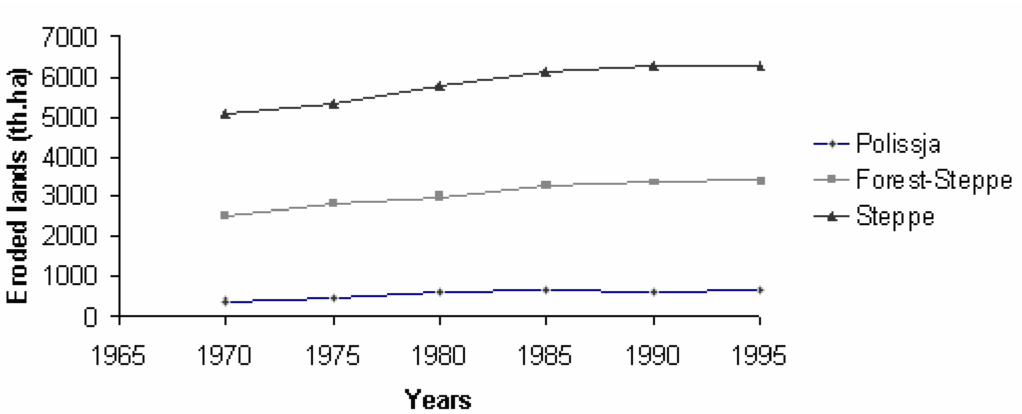


Figure 1 Erosion across forestry zones[3] in Ukraine

Source: NAS (1999)

Erosion causes substantial economic losses. Due to it, average agricultural losses of crops are up to 40% (NAS, 1998). If erosion spreads further with the same intensity, it will cause a decrease in productivity of 1/3 of arable lands. Annually, because of erosion, 4 Mt of fertile soil are washed out of the fields. Thus with the price of soil (fertilisers) 10 UAH[4] per tonne, annual damage to agriculture from erosion exceeds M€8. In addition, water erosion and floods in the Carpathians cause annual damage of about M€40 (Gensiruk, 1999).

Forests use ground water for transpiration, decrease soil humidity and prevent the spreading of erosion. Environmental functions of forest are essential, but according to the knowledge from the NAS (1999), the share of wooded area is insufficient. According to the NAS projections, and given the role of forest in alleviating erosion[5], the optimum[6] wooded

[3] The spatial classification of forests has been developed as a separate study with the aim as to enhance sustainability of forest resource use. See Gensiruk and Nijnik (1995) for further information.
[4] UAH (hryvna) roughly corresponds to €0.2.
[5] It is suggested that forest starts providing protection benefits after the age of 5 years (NAS, 1999), and with its gradual regeneration, it keeps providing protection effect for an indefinite period of time.

area in Ukraine should be 20%, and this will prevent further spatial spreading of erosion and its intensity (Table 1).

Table 1 Wooded Area in Ukraine per Forestry Zone, %

Forestry Zone	Original	Present	Optimum
Polissja	72.8	26.1	37.1
Wooded Steppe	52.0	13.0	16.8
Steppe	20.0	3.5	7.7
Carpathians	76.0	40.2	50
Crimea	14.2	10.0	12
Ukraine	44.4	15.4	20

Source: NAS (1998) and the State Committee of Forestry (SCF, 2000).

Considering the above, a sound policy measure to approach sustainable development is to expand forest cover.

Afforestation Potential Assessment

Afforestation is aimed at planting forests on low-productive agricultural land and bare land, and the creation of forests along rivers, canals and water bodies. It is expected that by planting trees, wooded area will increase by 20%. Consequently, additional wood will be produced, and the environmental situation will improve. The land that is suitable for afforestation includes: previously productive and wooded land in the Wooded Steppe, which was originally covered by forests, but has since been converted into land of other categories, including waste land; some marginal agricultural land; certain highlands not covered with forests in the Carpathian mountains; eroded and contaminated areas in various regions; land on sands, slopes, along roads, and around water basins; land around industrial agglomerations and land which is under recultivation (MEP, 1998):

Comprehensive Forestry Zoning (Gensiruk and Nizhnik, 1995) was used as a methodological background for assessing the possibilities of enlarging forest cover in Ukraine. The territory of the country has been divided into five main forestry areas, such as: the Polissja (Wooded Area), Wooded Steppe, Steppe, Crimea and the Carpathians with their subdivision into spatial units of lower levels of hierarchy, by taking into consideration landscapes development, soil distribution, climatic conditions, fauna and flora, etc.

[6] Optimum wooded area (OWA) is forest cover that allows sustain natural ecological balance. The projections on OWA were made on basis of environmental criteria with the focus on hydrological and soil protection functions that are deemed to be the priorities for Ukraine (NAS, 1998).

Afforestation potential was assessed across zones. A total of 0.4 Mha of land of the State Forest Fund (SFF) was defined as suitable for tree-planting.

In addition to the unused land of the SFF, bare and marginal agricultural land was considered for afforestation. It was also the land associated with forage and pasture and some marginal land used for wheat production, where the net returns from their current activities are low. Totally 2.29 Mha are suitable for afforestation. The potential comprises areas under management of the SCF and marginal agricultural land (Table 2).

Table 2 Potential for Afforestation by Land Use across Zones (1000 ha) [7]

Zones	State Forest Fund			Agricultural land			Totally
	ravines	sand	rocks	eroded	deflated	rocky	
Polissja	65.0	82.0	0.5	73.7	0.7	26.1	248.0
Wooded Steppe	95.0	84.0	0.6	451.6	18.3	61.0	710.5
Steppe	24.0	64.0	n.a.	669.4	40.6	137.5	935.5
Carpathians	1.6	n.a.	1.4	24.6	n.a.	143.4	171.0
Crimea	0.8	n.a.	1.8	13.1	1.8	206.8	224.3
Ukraine	186.4	230.0	4.3	1232.4	61.4	574.8	2289.3

Source: Estimated on basis of data of the SCF and State Committee of L and (1998)

The main economic task of tree-planting activity is to create during the shortest period of time highly productive, economically valuable and stable forest stands. In most cases mixed cultures are more productive and biologically stable. However, under marginal conditions, pure stands could grow, e.g. pure pine stands on very poor or dry soils. Taking into consideration tree growing conditions, the following main tree species are suggested for planting: pine in the Steppe and Crimea; pine and oak in the Polissja and Wooded Steppe; and beech, fir and spruce in the Carpathians.

Valuing Afforestation Costs

Since the land of the SFF has no alternative use to that of tree growing, the costs of its afforestation comprise tree-planting costs and silvicultural expenses. According to the Ministry of Environmental Protection (MEP 1998), the costs for creation of 1 ha of forest are €200, and the expenses for establishment of 1 ha of forest shelterbelt are €124.[8] These costs

[7] This is the maximum area suitable for tree-planting. After the estimation of NPV of afforestation, the area available for tree-planting was reduced at the account of land for which the opportunity costs appear to be comparatively high. According to the SCF, the whole estimate of land suitable for afforestation is over 1 Mha, with a potential increase of wooded cover to 16.1% (SFC, 2003).

[8] In 1994-1999, it was the Ministry of Environmental Protection and Nuclear Safety. Since the late 1999, it is the Ministry of Ecology and Natural Resources (SFF is within its organizational structure).

include tree-planting, and care and protection costs. Given different tree-growing and sustainable forest management conditions across forestry zones, the direct tree-planting costs, and care and protection costs are deemed to be equal within each forestry zone (Table 3).

Table 3 Afforestation Costs (€/ha)

Costs	State Committee of Forestry	Agricultural land
1.Tree-plating costs: first year costs (depend on forestry zone)	100-200	100-200
2.Care and protection costs, annual basis (depend on zone)	12.5-30	12.5-30
3.Opportunity costs of land, annual[9]	0	7-61.5

Source: Estimated on basis of data from the NAS (1998)

Afforestation costs for the SFF land differ from the costs for marginal agricultural land within the same zone, because agricultural land has alternative options for its use. Thus for agricultural land, in addition to direct costs of tree-planting and silvicultural expenses, the net returns associated with its current use, (opportunity costs of afforestation), are considered (Table 4). The estimates on net annual returns to current wheat production are computed on basis of NAS (1998) data on land productivity, costs of wheat production and output prices.

Table 4 Net Annual Returns to Current Agricultural Activities (€ per ha)

Forestry zone		Forage and pasture	Wheat production
Polissja	eroded and deflated land	8.0	37.8
	rocky land	7.8	n.a.
Wooded-Steppe	eroded land	10.0	52.1
	deflated lands	9.2	14.7
	rocky land	8.0	n.a.
Steppe	eroded land	20.0	61.5
	deflated land	6.0	27.2
	rocky land	n.a.	n.a.
Carpathians	eroded land	7.8	0
	rocky land	7.0	0
Crimea	eroded and rocky	7.0	0

Source: NAS (1998)

The households also use some marginal agricultural land suitable for forage production and pasture to feed their own cattle. There is no forage production provided to

[9] The opportunity costs will be higher, if to consider the case that after the conversion of a marginal land into forest, the Law will not allow the transference of this forest back to agriculture in a due term.

farmers. When the market does not function properly, it is impossible to evaluate the private market value of forage. The estimations are therefore based on productivity of land and prices which agricultural enterprises pay for the equivalent cattle feeding. Allowing for 100-years of stipulated ages of timber harvesting (SCF, 1998), a time horizon of 100 years is considered. The costs occurring over this period are converted into present value (PV) costs, at different discount rates (Table 5).

Table 5 Afforestation Costs by Forestry Zone, M€

Forestry zone	Annual Costs by Zone[10]			PV Costs			
	Opportunity	Planting	Care/Protection	r=0%	r=2%	r=4%	r=6%
Polissja	1.4	16.1	2.0	356.3	162.7	99.5	72.7
Wooded Steppe	6.4	32.8	4.1	1084.3	486.0	290.5	207.5
Steppe	14.1	49.8	7.1	2173.3	965.0	570.2	402.7
Carpathians	0.8	7.5	0.9	177.9	80.9	49.2	43.8
Crimea	0.8	19.6	2.5	345.0	159.9	99.4	73.7
Ukraine	23.5	125.8	16.6	4136.8	1854.5	1108.8	792.4

The results of the estimations are sensitive to discount rates. At 4% discount, the PV of afforestation costs is €484/ha on average for the country. The highest PV costs are in the Steppe (€609.5/ha, 4% discount), and the lowest are in the Carpathians (€288/ha, 4% discount). The divergence in costs is explained by the diversity of conditions.

Timber Supply Benefits

Afforestation focuses on establishing of a proper share between arable and wooded land in rural planning, where positive effects include direct user benefits, benefits of additional timber supply, and indirect user benefits obtained in agriculture as a result of soil protection function of forest which mitigate the expansion of erosion and alleviate the devastation of arable land.

A method of approximating a sum of monetary value for additional timber yield obtained from the potential plantations and a monetary estimation of soil protection benefits comprise the total benefits of afforestation. Regarding monetary value of timber yield changes, the employed model multiplies estimates of a physical crop change based on acreage in production, by the current price of timber (Hanley and Spash, 1993). This approach implies

[10] While annual costs of afforestation per ha come close to the estimates of MEP (1998), their figures on afforestation expenses for the country M€212 - M€290 are higher than our estimates, likely because additional expenses are necessary for afforestation of contaminated land, and we do not consider those.

an assumption that timber use and prices remain constant. Therefore, the estimates are initial approximations of the values of benefits to be obtained from additional timber supply via expanding of wooded area.

Allowing in a long-run for a stable average annual timber cut of about 2 m^3/ha on its present level that corresponds to 50% of mean annual increment (MAI), some 4.6 Mm^3 of additional timber could be produced, bringing annual returns of M€23. This volume of wood comprises roughly 30% of country's annual timber supply. In addition, the benefits from extra timber supply per forestry zone are computed over a 100-year period[11], and previously made estimation of annual returns to forestry is compared with the sum of the estimates received across forestry zones. Given the estimated growth functions of main tree species (Nijnik, 2002), pine in the Polissja has 250 m^3/ha, at harvest time. The stumpage value of timber is roughly €5/m^3 (Nilsson and Shvidenko, 1999). Thus, the returns per ha in the year of harvesting of pine stands appear to be €1250/ha. The returns from timber harvesting of all other major tree species across forestry zones are computed correspondingly (Table 6).

Table 6 Initial Estimates of the Returns from Timber Harvesting[12]

Forestry zone	Tree species	Stock of stands in 100 years, m^3/ha	Returns in the year of harvesting €/ha	PV returns €/ha,	PV returns by Zone M€			
				4%	0%	2%	4%	6%
Polissja	pine	250	1250	24.75	310.0	42.8	6.1	0.9
Wooded	pine	350	1750	34.65	612.9	84.6	12.1	1.8
- Steppe	oak	350	1750	34.65	612.9	84.6	12.1	1.8
Steppe	pine	250	1250	24.75	584.7	27.7	11.6	1.7
Carpathians	beech	350	1575	31.18	134.7	18.6	2.7	0.4
	fir	400	2000	39.6	171.0	23.6	3.4	0.5
Ukraine					2304.0	318.0	45.6	6.8

Source: Computed on basis of data from the SCF (1998).

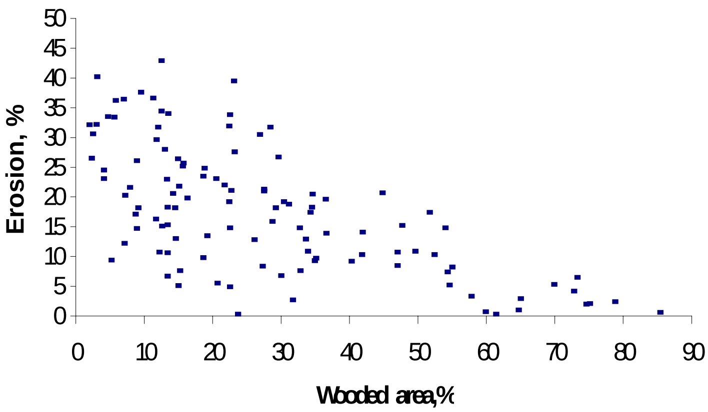
The following assumptions are made: stand composition in the Wooded Steppe comprises 50% of pine and 50% of oak trees; a half of the Steppe is planted with trees, precisely for protection purposes; and beech stands in the Carpathians are planted on 50% of the area, as are fir stands. In the Crimea, plantations are to be established only for environmental purposes. The PV returns from timber harvesting are sensitive to discount rates

[11] This roughly corresponds to stipulated ages of timber harvesting in the Ukraine (SCF, 1998)
[12] We take into account commercial timber cut and do not consider other use of the resources.

(M€ 2304, at 0% discount) and comparable with annual returns of M€23 estimated earlier. The highest benefits are in the Wooded Steppe.

Soil Protection Benefits

Numerous observations indicate that forest depletion and soil erosion are related phenomena



(NAS, 1998). The proposition that the scale of erosion in Ukraine depends on forest cover is put to an empirical test in regression analysis (Figure 2).

Figure 2 Relationship: Wooded cover - Erosion

The results of the estimations show statistically significant (at 1% significance level) negative relationship between the share of eroded land (E, %) and the share of wooded land (W, %) in rural areas of Ukraine:

$$log(E) = 3.4653 - 0.0329*W; \quad \text{or} \quad E = 31.986e^{-0.0329W}, \qquad R^2 = 0.45$$

(29.13) (-9.38)

The t-statistic of -9.38 suggests that the negative coefficient on W is significantly different from 0, and with the increase of forest cover, the erosion rates decrease. In addition, the relationship between forest cover and erosion is analysed per forestry zone. In the Carpathians, forest cover plays even a more important role in the prevention of erosion than for the country, in general:

$$log(E) = 4.3702 - 0.0523*W; \quad or \quad E = 79.059e^{-0.0523W}, \qquad R^2 = 0.50$$

(5.46) (-3.99)

The value of R^2 allows us to advocate that there is a room for the improvement of the model. Simulated rates of erosion are shown in Table 7.

Table 7 Simulated Rates of Erosion

Wooded area (W), %	Erosion (E), Ukraine, %	Erosion (E), Carpathians, %	Elasticity[13], Ukraine, %	Elasticity, Carpathians,%
0	32.0	79.1	-1.05	-4.13
5	27.1	60.9	-0.89	-3.18
10	23.0	46.9	-0.76	-2.45
15	19.5	36.1	-0.64	-1.89
20	16.6	27.8	-0.54	-1.45
25	14.1	21.4	-0.46	-1.12
30	11.9	16.5	-0.39	-0.86
35	10.1	12.7	-0.33	-0.66
40	8.6	9.8	-0.28	-0.51
45	7.3	7.5	-0.23	-0.39
50	6.2	5.8	-0.20	-0.30
55	5.2	4.4	-0.17	-0.23
60	4.4	3.4	-0.15	-0.18
65	3.8	2.6	-0.12	-0.14
70	3.2	2.0	-0.11	-0.11
75	2.7	1.6	-0.09	-0.08
80	2.3	1.2	-0.08	-0.06
85	2.0	0.9	-0.06	-0.05
90	1.7	0.7	-0.05	-0.04
95	1.4	0.5	-0.05	-0.03
100	1.2	0.4	-0.04	-0.02

The defined from the equations ratios of marginal changes in erosion rates to marginal changes in wooded cover rates are, as follows: for Ukraine, $dE/dW=-0.0329E$, and for the Carpathians $dE/dW=-0.0523E$. These estimations show the elasticity of erosion with respect to wooded cover in Ukraine and in the Carpathians. Until wooded cover is up to 27% in the Carpathains, and only when wooded cover in Ukraine is very low, the erosion is elastic. That means that when wooded cover is increasing marginally, the erosion is reduced proportionally as much. This is observed when the share of eroded lands is around 30% in Ukraine, and as far as it falls below 19% in the Carpathians. With further expansion of wooded cover, and consequently with further decreasing rates of erosion, it becomes inelastic. The regression suggests that if there were no woods in rural landscapes, the share of eroded lands would

[13] $\Delta E/\Delta W=\varepsilon\%$, 1% increase in W leads to ε % decrease in E. The figures on W and E are already given in percentage, thus it is not a straight forward computation of elasticity.

comprise 79% in the Carpathians and 32% on average for Ukraine. However, even if all rural areas were covered with forests, marginal erosion would exist anyway.

Using the results of the regression analysis on the elasticities of erosion with respect to forest cover, the initial average indicative estimates of soil protection role of forests per zone are computed. In the Polissja where wooded cover comprises 26%, the elasticity of erosion is -0.43% (Table 9). This means that 1% increase in wooded cover leads to 0.43% decrease in the erosion rates. In the Polissja, 1% increase of forest cover and that is an increase of 0.029 Mha, will mitigate erosion on 0.2 Mha of land in rural areas. The last figure is computed, as follows. Currently, erosion is spread on 13% of lands, or on 1.43 Mha. The decrease of erosion by 0.43% involves the area of 0.006 Mha. Therefore, the 0.029 Mha expansion of forest cover mitigates the erosion on 0.006 Mha of land. Hence, 1 ha of additional forest protects from erosion 0.2 ha of land. The net annual returns from 0.2 ha of agricultural land calculated on basis of data from Table 4, are about €1.6 for the land used for forage and pasture, and €7.6 for the land used for wheat production. These figures are indicative measures of soil protection benefits to agriculture from marginal expansion of forest cover in the Polissja. Similar estimations are made for the other forestry zones, and therefore the equation for calculation is, as follows:

$$X = \varepsilon \cdot E/W$$

where

ε elasticity of erosion with respect to forest cover, % (Table 7);

W share of wooded lands in rural landscapes, %;

E share of eroded agricultural lands, %;

Soil protection benefits to agriculture in the mountainous areas appear to be rather low due to the absence of wheat production, and because pastures are not common in the Crimea, where the level of precipitation is low. Though soil protection benefits to agriculture appear to be moderate in the Carpathians, in addition to the increasing returns in agriculture, the mountain forests provide essential environmental benefits (NAS, 1999). Their hydrological function is particularly important. Annually, in the prevention of floods and avalanches in the Carpathians, forest offers over €90/ha of non-marketed gains (Gensiruk and Ivanytsky, 1999).

In the Steppe, where forest cover comprises 3.5%[14], 1 ha of wooded land mitigates the erosion on 7.5 ha of land. Continual observations confirm that 1 ha of wooded land enlarges

[14] Together with the share of wooded cover, spatial distribution of fields and woods in rural landscapes plays important role in erosion mitigation, particularly in low-forested areas. Spatial sequencing of fields and forest shelter belts in rural areas is to be investigated further.

yield on the area of up to 25-30 ha (NAS, 1999). Forest has a great influence on the erosion rates in the Steppe, but this impact decreases with the increasing distance between forest and the agricultural land it protects. On average, gains in agricultural productivity are 15-20%, as compared with shelterless fields (MEP, 1998). These considerations are incorporated in calculations (Table 8). The assumption is made that in non-mountainous areas, 30% of agricultural land is used for wheat production.

Table 8 Indicative Measures of Soil Protection Benefits to Agriculture

Forestry zone	Annual average benefits, €/ha		Annual benefits
	Wheat	Forage/pasture	M€/zone
Polissja	7.6	1.6	0.8
Wooded Steppe	33.0	9.0	11.5
Steppe	58.2	17.0	27.5
Carpathians[15]	0	9.7	1.7
Crimea	0	12.2	2.7
Ukraine			44.2

According to Gensiruk and Ivanytsky (1999), forest provides soil protection benefits for prevention of sandy storms in the Steppe that are estimated at €86-93/ha. Overall, conversion of forest to row crops increases erosion by a factor of 20-1000, depending on the conditions (Van Kooten, 1993),[16] while the protection function of forest to alleviate erosion is argued to be around $30/ha (Lampietti and Dixon, 1995).

The results of the current analysis indicate empirically the dependence of erosion expansion from the share of wooded land in Ukraine and suggest on economic estimates of soil protection function of forest to agriculture. According to the estimations, annually, 1 ha of forest provides soil protection benefits to agriculture in the range of €1.6 to €58.2, with €19.3 on average for the country. The soil protection benefits of afforestation to agriculture are the highest in the Steppe zone of Ukraine.

Economic Evaluation

The analysis is carried out for Ukraine and across forestry zones (at discount rates 0-6%) considering various land users, tree species and 3 management regimes. CBA is conducted, where net present value (NPV) of afforestation is considered as the criterion for project evaluation. NPV determines the PV of net benefits by discounting the stream of benefits (B) and costs (C) back to the beginning of the base year $t=0$:

[15] These figures are relatively low, because they correspond to benefits that accrue solely to agriculture.
[16] 1000 stands for tropics.

$$NPV = \sum_{t=0}^{n} B_t/(1+r)^t - \sum_{t=0}^{n} C_t/(1+r)^t$$

Benefits from afforesation are expected to accrue over a long period of time, and 100 years are chosen to capture most of the benefits and costs (Table 9).

Table 9 Economic Evaluation of Afforestation, M€

Forestry zone	r %	PV timber benefits	PV erosion benefits	PV total benefits	PV costs	NPV
Polissja	0	310	84	394	356.3	37.7
	2	42.8	36.2	79	162.7	-83.7
	4	6.1	20.6	26.7	99.5	-72.8
	6	0.9	13	13.9	72.7	-58.8
Wooded Steppe	0	1125.8	1150	2275.8	1084.3	1191.5
	2	169.2	495.6	664.8	486	178.8
	4	24.2	281.8	306	290.5	15.5
	6	3.6	177.8	181.4	207.5	-26.1
Steppe	0	584.7	2750	3334.7	2173.3	1161.4
	2	27.7	1185.2	1212.9	965	247.9
	4	11.6	673.9	685.5	570.2	115.3
	6	1.7	425.2	426.9	402.7	24.2
Carpathians	0	305.7	170	475.7	177.9	297.8
	2	42.2	73.3	115.5	80.9	34.6
	4	6.1	41.7	47.8	49.2	-1.4
	6	0.9	26.3	27.2	43.8	-16.6
Crimea	0	0	270	270	345	-75
	2	0	116.4	116.4	159.9	-43.5
	4	0	66.2	66.2	99.4	-33.2
	6	0	41.8	41.8	73.7	-31.9
Ukraine	0	2303.6	4424	6727.6	4136.8	2590.8
	2	318.1	1906.7	2224.8	1854.5	370.3
	4	45.6	1084.1	1129.7	1108.8	20.9
	6	6.8	684.1	690.9	792.4	-101.5

The outcomes suggest that planting trees and establishment of a proper share of wooded and cultivated areas will contribute to timber supply and to the prevention of erosion, providing substantial benefits also to agriculture. The results of CBA depend on the discount rate. The NPV of afforestation is positive on average for the country, for the discount rates of

0%-4% (when its benefit/cost ratio is higher than 1). At these discount rates, afforestation enlarges social benefits to agriculture and forestry and adds to the welfare of society.

The observations across forestry zones give more precise results. Even if to limit benefits to timber supply gains and additional indirect user values of the project to agriculture, these benefits will already cover the costs of afforestation, at 0% - 2% in the majority of the zones. The investigation across forestry zones provides the following results: the area to be planted with trees is to be 2.07 Mha for the discount rate of 0% (excluding the Crimea); it is to be 1.82 Mha at discount rate of 2% (excluding the Crimea and Polissja); 1.65 Mha at discount rate of 4% (excluding the Crimea, Polissja and partly Carpathians); and its is to be 0.94 Mha if the discount rate of 6% is employed in CBA (when forest plantations will only be justified in the Steppe).

In the Carpathians and Crimea, commercial timber harvesting is restricted. The estimates of benefits from the extended timber supply are therefore modest in the Carpathians, and are not considered at all in the Crimea. Agricultural production is also limited in the mountainous areas and, therefore, the benefits that accrue to agriculture from soil protection forest function are moderate, as well. Consequently, NPV of afforestation is low in the Crimea and is moderate in the Carpathians. The CBA considers afforestation at various discount rates, yet without judging which exactly land (bare, marginal agricultural land currently used for forage, or pasture, or used for wheat production etc) is reasonable to convert into a wooded area, and which management regime is more preferable.

An LP Model for Forest Plantations

The model[17] considers bare and marginal agricultural lands suitable for afforestation in all forestry zones, with the exception of the Crimea. The timber production benefits from newly planted forests and soil protection forest functions are taken into consideration. Theoretical representation of the model presumes that the production function is multi-input and multi-output. The land and management regimes across forestry zones are inputs to the production system. The input of land comprises bare land and marginal agricultural land, such as pastures and the land presently used for forage and wheat production. Thus, trees can be planted on bare land, for which the opportunity costs of afforestation are deemed to be zero. Then, the area of forest may include the land which is presently used as pastures and for forage production. Further, it might be also reasonable to create forest on marginal agricultural land which is used for wheat production. This land currently provides positive net returns

[17] This simple model aims to provide some policy indication, without considering in-depth all land-use problems (see Nijnik, 2002).

associated with their agricultural activity. However, these returns might be insufficient and allow the conversion of the land into forest plantations.

The analysed management scenarios allow for different species composition of the projected forest. Pine and oak are main tree species grown in the Wooded Steppe and Polissja. Pine is considered for planting in the Steppe, and fir and beech, in the Carpathians. In addition to species composition, three forest management regimes are considered. The first regime is a basic silviculture (m_1). It is based on quick replanting of the desired tree species after harvesting that is often followed by brushing and weeding of tree stands. The reason for preferring a basic policy lies in the objective of forest companies to achieve quick full stocking and maximize volume of stands rather than to receive high quality wood (Wang and Van Kooten, 2001). The financial attractiveness of basic policy and the opinion that due to uncertainty it is reasonable to limit investment in incremental forest management allow considering a basic regime among the examined alternatives.

The second forest management regime (m_2) is that of planting trees and then attending all silvicultural operations prescribed by the rules of the Ukraine's forest legislation. The rotation ages are the same as under the first management regime. Currently, the Ukraine's forest law recommends harvesting of pine stands in 90 years, fir in 90-100 years, and oak and beech stands at 100 years of age. Before main cut, felling operations, called improvement fellings, take place. Clarification and cleaning are carried out in stands of up to 10 and 20 years of age, respectively. Thinning is carried out at the age below 40 years. Increment felling is the last felling operation performed in Ukrainian forests one age class before the main felling. Incremental forest management increases total productivity of forest stands by 5-10%, and of oak stands up to 16% (Gensiruk, 1992).

The third management regime (m_3) considers basic silviculture with the rotation period of timber that corresponds to maximum sustainable yield (MSY). Timber harvesting takes place as forest stands reach maximum of mean annual increment. The computed MSY rotation ages for each tree species across zones are 65-70 years (Nijnik, 2004). Sustainability is addressed within the modelling process through testing of the MSY timber rotation scheme for basic silviculture which is largely accepted among market-oriented forest practitioners.

The output set of the model comprises a marketed commodity (timber) and soil protection benefits of the forests, for which the values are imputed. The model provides some guidelines for the establishment of future forest in a way which allows, over a specified period, to achieve maximum cumulative NPV of timber and soil protection benefits from the forest subject to the constraints. A simplified mathematical framework of the model is:

$$Max\left\{\sum_{zatm} X_{zatm} \cdot O_{zatm} \cdot P_{at} + \sum_{zatm} B_{zatm} \cdot X_{zatm} - \sum_{zatm} X_{zatm} \cdot C_{zatm}\right\}$$

where

z = 1, 2, 3 & 4	forestry zones (1 - Polissja; 2 - Wooded Steppe; 3 - Steppe; 4 - Carpathians);
a = 1, 2, & 3	types of land (1 - bare; 2 - pastures and used for forage; 3 - used for wheat production);
t = 1, 2, 3 & 4	tree species (1 - pine; 2 - oak; 3 - beech; 4 - fir);
m	management regimes (m_1, m_2 and m_3) presented above;
X_{zatm}	the hectares of land "a" allocated in the zone "z", to be planted with "t" species scenario when management regime "m" is applied;
O_{zatm}	timber output per ha of "z" zone of land "a" planted with tree species "t" and treated with management regime "m", m^3/ha;
P_{at}	the discounted stumpage price of 1 m^3 of timber of tree species "t" grown on the type of land "a", €/m^3;
B_{zatm}	the discounted soil protection benefits of 1 ha of forest planted in the zone "z" on the land "a" with tree species "t" and treated with management regime "m", €/ha;
C_{zatm}	the discounted costs per ha during the rotation period in the zone "z" on the land "a" planted with tree species "t" and treated with the management regime "m", €/ha. The costs include direct tree-planting costs (including soil preparation), care and protection costs, timber harvesting costs and the opportunity costs of land.

The objective function then is maximized subject to the following constraints:

$$\sum_{tm} X_{zatm} \leq F_{za} \forall z, a$$

where F_{za} is total area in the zone "z" of the user "a".

$$X_{1a3m} = 0 \forall a, m$$

$$X_{1a4m} = 0 \forall a, m$$

$$X_{2a3m} = 0 \forall a, m$$

$$X_{2a4m} = 0 \forall a, m$$

$$X_{3a2m} = 0 \forall a, m$$

$$X_{3a3m} = 0 \forall a, m$$

$$X_{3a4m} = 0 \forall a, m$$

$X_{4a1m} = 0 \forall a, m$

$X_{4a2m} = 0 \forall a, m$

The above constraints imply that only main tree species "t" chosen for planting are to be planted across zones "a", whatever management regime "m" is applied.

$X_{424m} = 0 \forall m$

$X_{43tm} = 0 \forall t, m$

The last two constraints mean that in the Carpathians, beech forests do not grow on high altitudes, where main pastures are located, and that there are no lands suitable for wheat production in the mountains.

Results

The results provide evidence that, under the assumptions considered in this paper, and at discount rates as high as 4%, it is reasonable to plant trees only on bare land allocated for afforestation in the Wooded Steppe, Steppe and in the Carpathians. At 4% discount, e.g. the total area to be converted in forest is 0.42 Mha (Table 10).

Table 10 Some outcomes of the Model, 4% discount rate

Forestry zone(z)	Lands (a)	Area to be planted with trees (Fza), Mha	Tree species (t)	Management regime (m)	Shadow prices €/ha
Wooded Steppe	bare	0.28	oak	basic m_1	41.2
Steppe	bare	0.13	pine	basic m_1	245.2
Carpathians	bare	0.01	beech	basic m_1	59.5

The dual-primal property of LP problem is one of its useful features, because it yields shadow prices for the constraints. A shadow price indicates how much the value of the objective function changes if the constraint is changed by one unit. This is very important for sustainable management of forest when shadow prices often take the place of actual market prices as guides to the evaluation of non-marketable environmental services. The shadow prices of land appear to be the highest in the Steppe. Overall, it appears to be more efficient to establish monoculture forest plantations. Regarding management regimes, basic silviculture proves to be more rational in all forestry zones. These results could largely be explained by the fact that in this model the only user values to forestry and agriculture, are considered.

This model, however, does not allow for a really good comparison of timber rotation ages. The reason is that the period of time chosen for investigation is too short. Much better results could be obtained with its expansion, when several timber rotations are observed. Then, to harvest timber sooner rather than later could appear to be more economically efficient. This is because, with shorter rotation ages, as under the third management regime, more revenue flows will occur over a longer period. Afforestation has been assessed in its first approximation by using a static modelling approach and making an assumption that it could be implemented all at once, without taking into account its temporal and spatial sequencing. Though we do not expect that a dynamic approach will change study outcomes substantially, it has to be done in the future, with regard to policy-making objectives.

Discussion and Conclusions

Afforestation in Ukraine is seen as a means to contribute to sustainability of land-use management. For the excessively ploughed and sparsely wooded country, the expansion of its forest cover is important for a sustainable development. Much land is suitable for tree-planting, and the costs of afforestation, particularly direct tree-planting costs, are low in the country due to good forest growing conditions and low labour costs. Total benefits of afforestation considered in this paper include those of timber production and soil protection benefits to agriculture. Annually, 1 ha of forest in Ukraine provides soil protection benefits to agriculture in the range of €1.6 to €58.2[18]. The results of the statistical analysis suggest that planting trees and establishing of proper shares of wooded and cultivated areas will substantially contribute to the mitigation of erosion.

The results of CBA indicate that the costs for afforestation will be covered by the returns at 0% through 4% discount rates, on average for the country. The analysis conducted across forestry zones shows that the highest gains from afforestation are to be received in the Steppe zone. This result can be largely explained by forest function to alleviate soil erosion in the Steppe, where the erosion causes sandy storms and brings substantial economic losses. The benefits from afforestation are also high in the Wooded Steppe zone and Carpathians. The results of CBA provide evidence that, when only timber supply gains and benefits from the protection of agricultural land against erosion are taken into account, planting trees is not economically justified in the Polissja and Crimea, at 2% and higher discount rates. Thus, considering timber supply and soil protection benefits only, tree-planting in Ukraine is economically justified roughly on 1.82 Mha of land in the Steppe and Wooded Steppe zones, and in the Carpathains. When the discount rate of 4% is used, it is economically efficient to plant trees only on bare land in these zones, on the total area of 0.42 Mha.

Though planting trees will enlarge social benefits to agriculture and forestry, and will add to the welfare of society, welfare maximisation conditions will not be met, because of

[18] The range could be explained by the variety of conditions across Ukraine, which is one of the largest countries in Europe.

market failures. This justifies public policy concerning tree-planting. Because the costs of afforestation would largely be covered by the gains obtained in agriculture from the prevention of erosion, these social gains can not be achieved without government regulation. Therefore afforestation is to be implemented in Ukraine primarily as an administrative sustainable land-use policy measure, because of external benefits from forest and due to the shortage of economic incentives for tree-planting and growing. As the former practice of the establishment of forest plantations in Ukraine has shown, 70 thousands ha of land could be planted annually with trees (Gensiruk and Nizhnik, 1995). If that would be the same under the present and future institutions and economic conditions, it would take about 25 years, to implement afforestation of 1.82 Mha, It is hard to imagine that this is viable due to the shortage of investment and for other reasons.[19]

To conclude, the scope of the research can be extended, in the future, beyond soil protection and timber supply forest benefits. In the future studies, afforestation could be elaborated in view of economic, social and environmental benefits all at once. Results can be made more realistic by incorporating institutional constraints.

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[19] In this study, temporal and spatial dimensions of afforestation are not considered. For more discussion see Nijnik (2002) and Nijnik (2004).

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