Afforestation to increase the provision of ecosystem services: economic implications for Ukraine and beyond

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Abstract

This paper analyses costs and benefits of planting trees on marginal lands across forestry zones in Ukraine with the purpose of using them for timber production, erosion prevention and climate change mitigation. The research reveals that establishment of new forests to increase timber production and alleviate soil erosion is economically and environmentally justified in some regions. Incorporating the effects of afforestation through on climate change mitigation increases social benefits.

Keywords: afforestation, erosion, carbon, timber, cost-benefit analysis, Ukraine

Introduction

Forestry has traditionally been a sector of economy which primary objective was to maximize profits from timber production. Today the focus of forestry is wide, and recognition of a broad range of ecosystem services is the main stream of changes in analysing forestry development. Forests contribute to global carbon budget, provide biodiversity and aesthetic values, and serve as a basis for development of local entrepreneurial opportunities, outdoor recreation and rural livelihoods. Assessment of benefits of forest plantations has shifted from consideration of only production of (commodity) goods (timber) towards evaluation of multiple ecosystem services. The emphasis of this paper is therefore on consideration of broader forestry objectives, such as timber production, erosion alleviation and climate change mitigation. This paper firstly considers "user" benefits of afforestation that accrue to two primary sectors of Ukraine's ural economy, i.e. forestry and agriculture. Then, by considering carbon sequestration in trees it goes beyond the "user" benefits of afforestation by linking the planting trees in Ukraine to global climate change mitigation policy objectives.

Background

The history of establishment of forest plantations in Ukraine is dated back to the 17th century. However, since the early 1990s woodland creation has decreased due to institutional and economic reforms, and because of the policy shift from afforestation towards natural regeneration of forest. Nevertheless, reforestation coefficient stays 94%, planting on forestland amounts to about 28.5Kha; protective plantings on eroded and unproductive agricultural lands total 7Kha; and shelterbelt plantings total 1.1Kha per year (SCF 2007). The necessity of afforestation is pointed out in the President's Decree (2004) and in the State Programme (2002) "Forests of Ukraine, 2002-2015". The legislation rests on the principle of sustainable forest management, and multiple forestry objectives are recognised by the law (The Forest Code 2006).

Ukraine has good forest growing conditions and productive forests (Nijnik 2002). The territory was extensively covered with forests a millennium ago. Today, forest cover comprises 16.5%, and this is among the lowest estimates in Europe (FAO 2005). Given that 15% of the Ukraine's territory is under extreme anthropogenic pressures, and considering the role of forests for environment, the development of woodlands is considered important (MENR 2003). Ukraine has the level of cultivation of 54.8% by area and faces with partial erosion on 35% of its arable land. Annually, 4Mt of fertile soil are washed out. The damage to agriculture from erosion exceeds M€8. The intensity of soil erosion varies across the territory for which annual increment of eroded land is 90Kha. According to the National Academy (NAS 1999) wooded cover should go up to 20%, and this would alleviate spatial spreading of erosion and its intensity.

Conditional on its afforestation and sustainable forestry strategy, Ukraine could become self-sufficient in wood, and be a price setter in European wood production (Nijnik and Van Kooten 2000). This is because the demand for wood products in Europe is rising with 0.8-2.6% a year, and Europe will likely remain a high wood cost region. The niche for Ukraine's forestry in an international perspective is therefore its low cost of delivered wood (Nilsson and Shvidenko 1999). Moreover, afforestation has become a component of the Ukraine's climate policy meaning that over and above emissions reduction, an enhancement of carbon sink and storage in trees is becoming important. Numerous studies support the idea that a larger forest cover would be attractive in Ukraine (SCF 2007) but limited knowledge is available about the creation of multifunctional forest plantations to address wider sustainability objectives.

Afforestation potential

Afforestation potential was assessed across forestry zones. The land suitable for tree-planting was deemed to include bare land of the State Forest Fund (SFF) that is under management of the State Committee of Forests (SCF). The land suitable for afforestation also includes bare and marginal agricultural lands used for forage and pasture, and some land used for wheat production for which the net returns are low (Table 1).

Table 1 Potential for afforestation by land use across zones, Kha

Zones	State Forest Fund			Agricultural land			Total
	ravines	sand	rocky	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: Computed on the basis of the data from the SCL (2000)

Given the tree growing conditions and the assumptions based on interviewing of forest specialists (Nijnik 2002) pine was considered for planting in the Steppe, Crimea and Polissja; pine and oak in the Wooded Steppe; and beech, fir or spruce in the Carpathians.

Costs of afforestation

The costs of afforestation of marginal and bare land of the SFF include tree-planting costs (€100-200/ha) and silvicultural expenses (€12.5-30/ha annum). The costs vary, but given that within each zone the conditions are relatively stable, the costs are assumed to be the same within each zone. Marginal agricultural land has alternative options to afforestation. Therefore, in addition, the net returns associated with the current use of land were considered. The net annual returns to current wheat production were computed on basis of the data on land productivity, costs of wheat production and output prices. The estimation of costs for the land used for forage and pasture was based on land productivity and prices which agricultural enterprises pay for the equivalent cattle feed (Table 2). Computation was in Ukrainian national currency Hryvnya which in 2007 corresponded to 0.14 €.

Table 2 Net annual returns to current agricultural activities, €/ha

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

Source: NAS (1998)

The present value (PV) costs occurring over 100-years of stipulated ages of timber harvesting (SCF 2007) were estimated at several discount rates as seen in Table 3.

Table 3 Afforestation costs, M€

Forestry zone	Annual costs by zone			PV costs			
	Oppor-tunity	Planting	Care & Protection	r=0%	r=2%	r=4%	r=6%
Polissja (Woodland)	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 show that at a 4% discount rate, the PV of afforestation costs is €484 per ha on average for the country. The highest PV of costs is in the Steppe €609.5 per ha, with the lowest of €288 per ha in the Carpathians. The divergence in cost estimates across zones is explained by the diversity of tree-growing and socio-economic conditions.

Timber supply benefits

A sum of monetary value from additional timber yield and monetary estimates of soil protection pertaining to arable land comprise the total benefits of afforestation (when only “user benefits” to forestry and agriculture are considered). For the monetary value of timber yield changes, the model multiplies estimates of a physical crop change based on acreage in production by the price of timber (Hanley and Spash 1993). This implies that timber use and prices are constant. Allowing in the long-run for a stable average annual timber cut of 2 m^3/ha (c. 50% of mean annual increment) about 4.6Mm^3 of additional timber could be produced, bringing annual returns of M€23, if the stumpage value of timber is c. €5/m^3 by Nilsson and Shvidenko (1999).

The benefits were also computed across zones over a 100-year period. Table 4 shows the results when only commercial timber cut is taken into account. The following assumptions were made: stand composition in the Wooded Steppe comprises 50% of pine and 50% of oak trees; half of the Steppe is planted with trees which would be harvested, and beech stands in the Carpathians are planted on 50% of the area, as are fir stands. The Crimea where forests play primarily environmental role was not considered.

Table 4 Estimates of the returns from timber harvesting

Zone	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
Carpa-	beech	350	1575	31.18	134.7	18.6	2.7	0.4
Thians	fir	400	2000	39.6	171.0	23.6	3.4	0.5
Ukraine					2304.0	318.0	45.6	6.8

The table suggests that at the discount rate of 0%, PV returns from timber harvesting are M€23.04 (comparable with the annual returns of M€23 estimated earlier). The highest returns per acreage are in the Wooded Steppe and the Carpathians. However, only the timber benefits do not justify the tree-planting in any of the zones.

Soil protection benefits

The notion that the scale of erosion depends on forest cover (NAS 1998) was put to an empirical test by using a semi-logarithmic regression (Figure 1), and economic attractiveness of planting trees to mitigate erosion was then assessed.

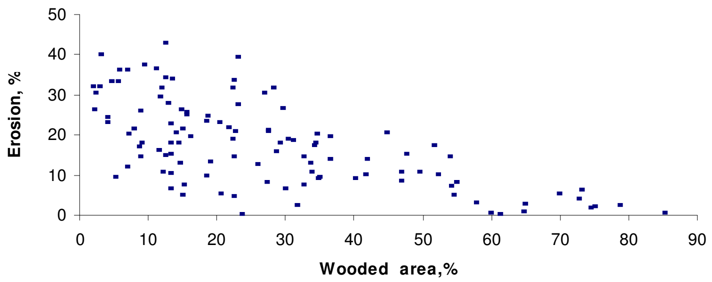

Figure 1 Relationship: Wooded cover - Erosion

The results of the estimation show a statistically significant (at 1% significance level) negative relationship between the share of eroded land (E, %) and the share of wooded land (W, %):

$$log(E) = 3.4653 - 0.0329*W; \quad \text{or} \quad E = 31.986e^{-0.0329W}, \quad R^2 = 0.45$$
(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. The value of R^2 indicates that more factors influence erosion but wooded land is important.

For the Carpathian Mountains where the conditions differ substantially from elsewhere in the country (lowland) the estimated equation is as follows:

$$log(E) = 4.3702 - 0.0523*W; \quad or \quad E = 79.059e^{-0.0523W}, \quad R^2 = 0.50$$
(5.46) (-3.99)

Simulated rates of erosion at different levels of wooded cover are shown in Table 5.

From the estimated equations, marginal changes in erosion rates to marginal changes in wooded cover rates are 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. The results indicate that until wooded cover is up to 27% in the Carpathians and c. 2% in Ukraine, the erosion is elastic, i.e.

when wooded cover is increasing marginally, the erosion is reduced proportionally as much. This is observed up to the point when the share of eroded land is around 30% in Ukraine, and as far as it falls below 19% in the Carpathians. The results suggest that if there were no woods in rural areas the share of eroded lands would comprise 79% in the Carpathians and 32% on average in Ukraine.

Table 5 Simulated rates of soil erosion

Wooded area (W), %	Erosion (E), Ukraine, %	Erosion (E), Carpathians, %	Elasticity, 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

By using the results of regression analysis indicative estimates of soil protection role of forests were computed. In the Polissja where wooded cover comprises c. 26%, the "elasticity" of erosion is -0.43%. This means that a 1% increase in wooded cover leads to a 0.43% decrease in the erosion rates. A 1% increase of forest cover, i.e. an increase of 0.029Mha will mitigate erosion on 0.2Mha of land. The net annual returns were then calculated on the basis of data from Table 2 and were considered as measures of soil protection benefits to agriculture from marginal expansion of forests in the Polissja. The corresponding estimations were made for other zones, and the equation for calculation is:

$$X = \varepsilon E/W$$

X indicative measure of soil protection benefits to agriculture from marginal expansion of forest cover;

ε "elasticity" of erosion with respect to forest cover, i.e. 1% increase in W leads to ε % decrease in E, % (Table 5);

W share of wooded land, %;

E share of eroded agricultural land, %

Forests start providing protection benefits after the age of 5 years and with their gradual regeneration, forests keep providing these benefits indefinitely (Gensiruk and Ivanytsky 1999). These and other considerations (Nijnik, 2002) were taken into account when computing economic estimates of soil protection function of forest to agriculture. The potential for forest expansion was taken from Table 1 and the assumption was made that in non-mountainous areas, 30% of agricultural land is used for wheat production. The results indicate the dependence of erosion from the share of wooded land (Table 6). The soil protection benefits of afforestation to agriculture are the highest in the Steppe.

Table 6 Estimates of soil protection benefits to agriculture

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

An LP model for forest plantations

The economic analysis of afforestation was carried out at various levels of hierarchy. In this section, only "user" net PV benefits of afforestation to forestry and agriculture in Ukraine are considered. The idea of the model is to provide some guidelines for the establishment and management of forests so as to achieve maximum cumulative net PV benefits from tree plantations over the period of timber rotation subject to constraints. In the following section, the analysis is presented at a higher hierarchical scale, but in addition to "user" benefits of afforestation, carbon sequestration in trees is incorporated in the analysis.

The following model considered planting of pine and oak in the Wooded Steppe and Polissja; of pine in the Steppe; and of fir and beech, in the Carpathians. Three forest management regimes were considered. A basic silviculture (m_1) is based on quick replanting of the trees after harvesting. The second regime (m_2) is that of planting trees and attending silvicultural operations recommended by the Ukraine's legislation. The third regime (m_3) is basic silviculture with the maximum sustainable yield rotation ages of 65-70 years, by Nijnik (2002).

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

$z = 1, 2, 3, 4$ forestry zones;
$a = 1, 2, 3$ types of land (1-bare; 2-pastures and forage; 3-wheat);
$t = 1, 2, 3, 4$ tree species (1-pine; 2-oak; 3-beech; 4-fir);
m management regimes (m_1, m_2, m_3);
X the hectares of land;
O_{zatm} timber output, m^3/ha;
P_{at} the discounted stumpage price of timber, €/m^3;
B_{zatm} the discounted soil protection benefits of 1 ha of forest, €/ha;
C_{zatm} the discounted costs per ha during the rotation period, €/ha.

Major constraints of this model were acreage, e.g.:

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

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

The constraints (see Nijnijk, 2002) also meant that only main tree species "t" specified for planting are to be planted in "a", whatever management regime "m" is applied. They also implied e.g. that in the Carpathian Mountains, beech forests do not grow on high altitudes or that there is no land suitable for wheat production in the mountains.

The results of LP modelling provide evidence that under the assumptions and at discount rates 4%, it is economically sound to establish monoculture plantations on the perceived bare land in the Wooded Steppe (0.28Mha), Steppe (0.13Mha) and the Carpathians (0.01Mha). The shadow price of bare land (245.2€/ha) is the highest in the Steppe.

Costs and benefits of afforestation

In addition to domestic gains to forestry and agriculture afforestation provides climate change mitigation benefits. The economics of carbon sequestration forestry scenarios as a stand along analysis is in Nijnik (2005). In the current paper, economic evaluation of tree-planting for multiple purposes, including for carbon sequestration under the storage policy scenario is presented. This scenario presumes one-time planting of trees for a period of 100 years, without accounting for future use of wood and land (Van Kooten and Bulte 2000). The analysis was carried out across zones when maximising of net PV of afforestation was considered as the criterion. The 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*:

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

The carbon (C) uptake benefits have been approximated through the following procedure. The functional forms for stand growth of the tree species were estimated, with the equations provided in Nijnik (2002). The coefficients of Lakida *et al*. (1995) were used to translate the stem biomass into total above ground biomass. The volume of stem wood was multiplied by $0.2tC/m^3$ for its translation into carbon (Jessome, 1977). Carbon sequestered by the root was estimated, depending on the species, either on basis of the relationships presented in Van Kooten and Bulte (2000), or in Lakida *et al*. (1995). Then, based on Nijnik (2005), the sequestered C was computed across zones. The price of 15€ per tonne of C was assumed stable and used to calculate carbon uptake benefits based on Sandor and Skees (1999). The discount settings of 0%, 2% and 4% were applied when the carbon storage option was considered. The PV benefits from afforestation are shown in Table 7.

Table 7 Afforestation benefits, PV M€

Forestry zone	r%	Production	Soil protection	Carbon uptake
Polissja (Woodland)	0	310	84	362.6
	2	42.8	36.2	49.1
	4	6.1	20.6	6.6
Wooded Steppe	0	1125.8	1150	1255.9
	2	169.2	495.6	170.1
	4	24.2	281.8	23.0
Steppe	0	584.7	2750	1237.4
	2	80.7	1185.2	167.5
	4	11.6	673.9	22.7
Carpathians	0	305.7	170	660.7
	2	42.2	73.3	89.4
	4	6.1	41.7	12.2
Crimea	0	0	270	437.3
	2	0	116.4	59.2
	4	0	66.2	8.0

The results presented in Table 8 suggest that e.g. in the Polissja the highest benefits would come from the increased timber production and carbon uptake, whilst in the Steppe they would occur due to the soil protection forest function.

Table 8 Economic evaluation of afforestation across zones, PV M€

Forestry zone	r %	Total benefits	Costs	NPV
Polissja (Woodland)	0	756.6	356.3	400.3
	2	128.1	162.7	-34.6
	4	33.3	99.5	-66.2
Wooded Steppe	0	3531.7	1084.3	2447.4
	2	834.7	486	348.7
	4	329.0	290.5	38.5
Steppe	0	4572.1	2173.3	2398.8
	2	1433.4	965	468.4
	4	696.6	570.2	126.4
Carpathians	0	1136.4	177.9	958.5
	2	204.9	80.9	124
	4	59.9	49.2	10.7
Crimea	0	707.3	345	362.3
	2	175.6	159.9	15.7
	4	74.2	99.4	-25.2

The NPV of afforestation is positive in the majority of the zones for discount rates of up to 2%. At a discount rate of 4%, the area of forest plantations is to be 1.82 Mha (excluding the Crimea and the Polissja). In the Carpathian and Crimean Mountains, commercial timber harvesting is restricted, and economic benefits from timber are therefore modest. Agricultural production is limited in the mountainous regions too. Consequently, the benefits that accrue to agriculture from soil protection forest function are moderate.

Conclusions

Afforestation in Ukraine, where the vast areas are suitable for tree-planting, is seen as a means to contribute to sustainable land management and climate change mitigation. The afforestation costs are low, apparently due to good forest growing conditions and relatively low labour costs. An expansion of forest cover is important with regard to soil protection. Annually, 1 ha of forest in Ukraine provides soil protection benefits to agriculture of €1.6 to €58.2. Such a broad range can be explained by the variety of conditions. A low share of forest cover might be among the causes of erosion and planting trees is a possible measure to alleviate it, particularly in the Steppe.

When only timber production gains and those from the protection of agricultural land against erosion are taken into account, at 2% through 4% discount rates, the benefits from afforestation are high in the Steppe, Wooded Steppe and the Carpathians, where the tree-planting is economically justified on c. 1.82Mha of land. When a discount rate of 4% is used, the planting of trees is to be limited to bare land in these zones, with the total area of 0.42 Mha.

The results are more positive when afforestation considerations include the rewards for climate change mitigation. But with or without a consideration of carbon uptake, at discount rates lower than 2%, the costs for afforestation will be covered by the returns in the majority of regions. The results indicate that whilst soil protection benefits from afforestation in the Steppe are expected to be high, the carbon sequestration and timber production activities are not cost-efficient due to low rates of tree growth and relatively high opportunity costs of land. The opportunity costs of land are also high in the Polissja where afforestation is cost-inefficient at 2% and higher discount rates.

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