Ecosystems, Sustainability and Growth for Sweden during 1991-2001

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Abstract

The purpose of this paper is to present calculations of non-marketed values of changes in Swedish natural capital assets. The value of changes in natural capital, or wealth change, is then estimated as net values of current and future production of non-marketed ecosystem services. Values are calculated for ecosystem supply of recreational values and pollutant cleaning from four classes of natural capital assets: forests, agricultural landscape, wetlands, and air quality. The demonstration shows that the net welfare contribution from these natural capital assets during the period 1991-2001 is positive, but that the use of the assets is unsustainable. A comparison of conventional NDP and adjusted NDP shows a significant difference, and also that growth can change in different directions depending on which measurement is used.

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JEL classification: D6, D9, O4, Q2

Key words: natural capital, ecosystem services, sustainability, growth

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1. Introduction

Sustainability and growth have been the objects of many studies during the last century. Much of the debate on the meaning and measurement of sustainability took off in association with the Brundtland report (World Commission, 1987). In the Brundtland report, sustainable development is, in principle, characterised by consumption today, which does not impinge on the consumption possibilities of future generations. Since then, there has been an ongoing debate on sustainability, its components and their measurement (see e.g. Perman et al. 2003). A common agreement among scientists is the importance of natural capital for sustainable development (e.g. Fenech et al. 2003). In economics, we find in principle two types of approaches for defining and measuring sustainable uses of natural capital. One approach is to find income along a sustainable development path (e.g. Hartwick 2001), and the other is to relate sustainable consumption to the capital asset base (Dasgupta and Mäler 2000, 2001). Sustainability according to the first approach is usually defined as non-declining consumption during time and to the other as non-declining wealth. Under quite restrictive conditions on utility preferences and the functioning of markets, the two approaches are very similar. However, these conditions are likely not to hold, and as convincingly argued by Arrow et al. 2002, changes in wealth are likely to reflect future consumption possibilities in a more appropriate way than does income along a sustainable path.

However, regardless of perspective and definition of sustainability, conceptualisation and empirical measurement of natural capital is far from established. In principle, we find three types of natural capital concepts; resources like oil and arable land, pollution or pollution stock, or inputs into production of ecosystem services. The two first alternatives are most common, see e.g. Heal and Kriström (2001) for a review of natural capital in green accounting framework. In a few studies natural capital is regarded as input into production of a broad spectrum of marketed and non-marketed ecosystem services, such as provision of food, recreational values, and pollutant sinks (e.g. Arrow et al. 2002; Dasgupta and Mäler 2000, 2001). According to these studies, changes in natural capital assets should be valued on the basis of their accounting prices, which are defined as the impact on current and future well-being from a marginal change in the capital assets. It is, however, unclear how these accounting prices are to be determined. Since ecosystems such as forests, lakes and wetlands provide ecosystem services, it seems relevant to regard ecosystems as natural capital assets, and the accounting prices are then determined by their streams of current and future net utility. Although simple in principle, there is a significant challenge associated with the quantification and valuation of non-marketed ecosystem services, such as recreational values and carbon sequestration. The purpose of this paper is to show how the value of natural capital as inputs into production of non-marketed services can be calculated for the Swedish natural capital assets wetlands, forests and agricultural landscape. These estimates are then used for assessing sustainable use of Swedish capital assets and comparing growth as measured by net domestic product with and without the inclusion of ecosystem services.

This study differ from most other studies of similar purpose with respect to the treatment of natural capital as ecosystems, which, in turn, are regarded as inputs for production of ecosystem services. A more common approach for assessing environmental changes has been to include pollution or pollution stock in society's welfare function and/or in production functions for marketed outputs. The reason for not following this commonly applied approach in this paper is the perception that it is not pollution per se that is of interest for society, but rather the functioning of ecosystems and their role for society. Only if there is a clear correlation between emission of pollutants and ecosystem functioning, the simplification of treating natural capital as pollution can be meaningful.

The production functions for ecosystem services differ among ecosystems. Common to most ecosystems is the role of biodiversity, carbon-, nitrogen- and water cycles for their functioning as well as human impact like land management and pollution (e.g. Daily et al. 1997). In general, pollution has a negative impact on the production of ecosystem outputs beyond a certain pollutant concentration. This critical level differs among ecosystems, and up to a certain level of pollution there is no impact at all. When this threshold level is reached, which may take many periods of time, further pollution adventure the ecosystem functioning and thereby its provision and composition of outputs. It may even be the case that utility increases for certain output changes and decreases for others. One example is a lake where heavy pollution loads decreases biological life, which reduces the availability of food in the lake, but raises the recreational value from higher water transparency. Thus, the introduction of pollution in the utility functions without consideration of the impact on ecosystem and their functioning seems not to have much support from the biological disciplines.

There are a few empirical studies of natural capital and its role for wealth, sustainability and growth (Hamilton and Clements, 1999; Gylfasson 2001; Aniar, 2002; Vincent, 2001; Sachs and Warner, 2001). The Hamilton and Clements (1999) study estimates and compares wealth – natural, human and produced capital – and income as measured by GDP for 100 countries in 1994. Natural capital then consists mainly of natural resources such as arable land, and the study shows that natural capital is associated with low income growth countries. These results are confirmed by Gylfasson (2002) and Sachs and Warner (2001). However, GDP/capita does not account for depreciation of capital, and it would therefore be more adequate to compare net domestic product, NDP, per capita across time and among countries. Furthermore, conventional GDP and NDP measurements of growth imply that non-market ecosystem services are not included as part of the economic activities in the nations. In this paper, NDP is therefore used to compare the differences in Swedish growth of economic activity during 10 years with and without the inclusion of non-marketed ecosystem services.

The paper is organised as follows. First, the method for calculating the consumption and investment values of natural capital is briefly described. Chapters 3-7 present calculations of values of changes in the natural capital assets forest, wetlands, agricultural landscape, and urban systems. Then, an indicator of sustainable use of these assets is calculated, which, in turn, is compared with changes in all other assets in order to derive a more general sustainability measurement. Next, growth in net domestic product is compared with net domestic product accounted for environmental use. The paper ends with a discussion of the results.

2. Ecosystem services as determinants of the accounting prices of natural capital: a brief presentation

Accounting price of capital is defined as the impact on well being from a marginal change in the capital asset in question (see Arrow et al, 2002; Dasgupta and Mäler 2000, 2001). The accounting prices are then measured as the value of a marginal capital change given the institutional set up in the country, that is mechanisms for resource allocation such as laws and markets. The accounting prices thus not necessarily reflect optimal use of the capital assets, but can still be used as determinants of well being for small changes in the capital assets. As discussed in Dasgupta and Mäler (2000), the only requirement is that the society's wellbeing is continuous in its arguments. This is supposed to hold for the natural capital assets included here.

However, the links between capital assets and well being, or the determinants of accounting prices, need to be identified if they are to be used in practice. In this paper this is made through the capital assets' provision of ecosystem services that enter the utility function and/or production functions of marketed goods and services, see Gren (2003). In principle, the calculation of accounting prices and consumption values of ecosystems as natural capital then consists of three interrelated parts: *i)* quantification of the stock of each ecosystem and its change during time, *ii)* establishment of the relations between production of outputs and ecosystem stock levels, and *iii)* estimation of unit net values of the ecosystem outputs.

Under the first point, a practical difficulty arises in the choice of relevant natural capital assets. The exemplification in this paper follows UN (2002) ecosystem classification, which distinguishes between two broad classes of ecosystems: aquatic and terrestrial. The choice here is also dependent on the availability of data. In the sequel, calculations are therefore made for forests, agricultural landscape, wetlands and urban system.

Although the classification of ecosystem poses a challenge, an even more difficult task is to find production functions for these ecosystems which relate outputs to the level of natural capital. The choice of outputs is dependent on possibilities of doing this and also on the availability of estimated values of these outputs. Two types of outputs are therefore included; recreational and pollutant sink values. Except for urban systems, recreational values are calculated for all ecosystems. Carbon dioxide sequestration values are estimated for forests, and nitrogen sink values for wetlands. Monetary estimates of urban systems are made for health impacts of changes in air quality in densely populated regions.

Once the natural capital assets and their production of ecosystem services are identified and quantified it remains to obtain unit output values. Since the outputs included here are not subjected to market transactions, their valuation need to be obtained through other channels. Techniques for the measurement of changes in non-marketed environmental services have developed rapidly since 1970s (see e.g. Turner et al., 2003 for a review). The estimates used here are derived from various Swedish valuation studies, which apply most of the valuation tools available (see Sundberg and Söderqvist , 2004 for a survey). Due to lack of data it is also assumed that there are no management costs associated with the provision of the included ecosystem services. For forests and arable land, the services are treated as by-products of production of marketed outputs, and this assumption is therefore valid. However, the exclusion of management costs implies an overestimate of the value of services of wetlands since there are in general cost associated with the management of wetlands as pollutant sink (see e.g. Byström, 1998).

In an elongated country like Sweden, the production functions for ecosystem services and their values are likely to differ among regions. Regional estimates are therefore made when data is available, which results in a disaggregation of wetlands and agricultural landscape into two and three Swedish regions respectively. Calculations are made for the period 1991-2001, which is limited by the availability of, in particular, wetland data.

For each natural capital asset and output, consumption and investment values are calculated. Consumption values refer to the monetary estimate of the flow of outputs that the natural capital assets provide each period. Investment is the value of the change in a natural capital asset during a period, which is calculated as the value of the associated changes in future supply of ecosystem services. Values of changes in future ecosystem outputs are discounted with assumptions of continuous time and unlimited time perspective. A common choice of the discount rate is that suggested by Ramsey (1928), according to whom the discount rate is determined by pure time preferences, or the utility discount rate, and growth rate. For a constant utility discount rate this would imply a falling discount rate when the growth rate is increasing. More recent research also points at a declining discount rate with respect to distant future (Weitzman, 2001). However, the change in growth rate and discount rate is difficult to determine empirically, and a constant real discount rate of 3 per cent is therefore assumed. This rate is close to the rate of interest on Swedish governmental bonds.

3. Forests

Forests provide a variety of values for society such as timber, biodiversity, carbon uptake etc. This was recognised in the early 1990's as documented by, among others, Hultkrantz (1992). The sink capacity for a given area is mainly determined by the forest growth, which, in turn, depends on a number of factors such as climate, type of forest trees, soil, etc. (see e.g. Olsson, 2003). Depending on forest management – harvesting and plantation – sink capacity can be increasing, decreasing or unchanged over time. Valuation of this carbon sequestration can follow two approaches. One is to estimate the environmental damage that is avoided through the carbon sequestration, and the other is to estimate avoided cleaning costs for a given carbon emission target. Since the first approach is almost impossible to apply due to the difficulties of assessing damage and valuation functions, the second valuation method is used in this paper.

During 1990-2001 the total CO_2 uptake of Swedish forests varies between 21 and 29 millions ton, see Table 1. The uptake exceeds the Swedish commitment under the EU agreement of reducing carbon dioxide reduction, which corresponds to 2.7 millions tons of CO_2 (EC, 2000). The value of the sink capacity depends on alternative ways of reducing carbon emission. If the only alternative is to reduce Swedish emission from energy combustion in all sectors, the average marginal impact on GDP would be SEK 0.6[1]/kg CO_2 (Östblom, 2002). However, the cost of Swedish emission reductions would be reduced if emission trading could be made with outside sources. The marginal impact at the same level of emissions depends on the equilibrium market price, which differ considerably among studies. In this paper, the equilibrium price used by Östblom (1999) is used, which gives the price of 0.38 SEK/kg CO_2.

In order to calculate the value of investment we use biomass growth as a stock variable. According to Olsson (2003), the net carbon storage amounts to approximately 1/8 of the gross storage during one year. It is assumed that this storage is due to the change in biomass growth. The stock change is then calculated as 1/8 of the carbon sequestration divided by the growth in biomass, which is multiplies by the change in biomass growth.

Table 1: Carbon sink values from Swedish forests, billions of SEK in 2001 year prices.

Year	Change in biomass $10^6 m^3$ [1]	CO^2 seq, mill ton [2]	Cons. value, bill SEK[3]		Investment value, bill SEK[4]		Total value	
			Low	High	Low	High	Low	High
2001	13,0000	29.3	11,13	17,58	17,89	28,17	29,02	45,75
2000	8,0000	23.5	9,15	14,45	-62,11	-97,82	-52,96	-83,37
1999	21,0000	29.3	11,53	18,20	-4,59	-7,22	6,94	10,98
1998	23,0000	26.3	10,39	16,40	-7,55	-11,89	2,84	4,52
1997	27,0000	21.2	8,37	13,21	-11,65	-18,35	-3,28	-5,14
1996	36,0000	22.3	8,85	13,97	0,00	0,00	8,85	13,97
1995	36,0000	27.3	10,89	17,19	18,95	29,84	29,83	47,03
1994	21,0000	24.3	9,93	15,68	-35,55	-55,99	-25,63	-40,31
1993	39,0000	27.3	11,39	17,98	21,96	34,58	33,34	52,56
1992	21,0000	27.3	11,92	18,83	26,09	41,09	38,02	59,92
1991	10,0000	29.4	13,14	20,75	16,47	25,94	29,62	46,69
1990	7,0000	29.3						

1. National Board of Forestry, 1990-2003, standing volume
2. Forsgren (2003)
3. 0.38 or 0.6 bill sek per mill ton carbon sequestration times carbon sequestration
4. 12.7 or 20 bill sek per mill ton carbon sequestration times (0.13xcarbon sequestration/$10^6 m^3$) times $10^6 m^3$ change of growth in standing volume

[1] SEK 9.22 = EURO 1 (March 4, 2004)

The consumption value varies from 8.37 to 20.75 billions of SEK depending on year and marginal valuation of carbon sequestration, and the investment value ranges between –93.90 and 39.45. During the years under study, there has been a net degradation of forests' carbon sequestration, which is due to the net negative change in biomass growth.

Recreational values include a number of activities, such as hunting, picking of mushrooms and berries, sporting and walking. A survey of studies with estimates of such recreational values from Swedish forests is made by Jämttjärn (1996). The average value per person and year amounts to SEK 3000, which corresponds to SEK 795/ha forest. The variation is, however, large among studies ranging from approximately 0.4 to 2 times of the average value.

In order to find a recreational investment value for forests it seems reasonable to use another stock variable than for carbon sequestration. Instead, change in area of forest land is applied as a measure of stock changes. The accounting price of forest is then found by assuming that the value of forest is the same irrespective of regional location. However, most of the reviewed valuation studies in Jämttjärn (1996) are made for areas with relatively high visiting frequency, and a relevant estimate of stock change would require investigations of regional changes in forests. This is not available, so calculations are therefore made for the lower and upper values as reported in Jämttjärn, 1996.

Table 2: Recreational values from Swedish forests, billions of SEK in 2001 year prices.

Year	Area of forests, 1000 ha[1]	Consump tion value, bill SEK[2]		Change in forest area, 1000 ha	Investment value, bill SEK[3]		Total value	
		Low	High		Low	High	Low	High
2001	22 614	7,69	38,44	-5	-0,06	-0,28	7,63	38,17
2000	22 619	7,88	39,40	-121	-1,39	-6,89	6,49	32,50
1999	22 740	8,00	40,02	127	1,47	7,31	9,48	47,33
1998	22 613	7,99	39,96	-8	-0,09	-0,46	7,90	39,50
1997	22 621	7,99	39,93	-15	-0,17	-0,87	7,81	39,07
1996	22 636	8,03	40,17	59	0,69	3,42	8,72	43,59
1995	22 577	8,05	40,27	59	0,69	3,44	8,75	43,72
1994	22 518	8,23	41,16	-221	-2,66	-13,21	5,57	27,95
1993	22 739	8,49	42,43	-167	-2,05	-10,19	6,43	32,24
1992	22 906	8,95	44,76	-95	-1,22	-6,07	7,73	38,69
1991	23 001	9,20	46,00	-264	-3,48	-17,27	5,72	28,73
1990	23 265							

1. National Board of Forestry, 1990-2003
2. 0.34 and 1.70 mill SEK /1000 ha times forest area. Jämttjärn (1996)
3. 11.2 and 55.6 mill SEK /1000 ha times change in forest area

The total recreational values, annual consumption plus investment, is of the same magnitude as the value of carbon sequestration. There is a decline in forest area during the period 1990 to 1994, which implies negative investment and then reduces the total value.

4. Agricultural landscape

The agricultural landscape provides a number of non-marketed ecosystem services from its mix of various land uses for grazing, cereal production etc. Marked transitions from one land type to another, such as ditches, are usually rich of biodiversity. Further, traditionally managed agricultural landscapes provide scenic beauty, which can generate recreational values. Two studies have estimated the value of Swedish agricultural landscape (Drake, 1992; Hasund, 1998). Drake estimates the willingness to pay for the agricultural landscape in general, and Hasund focus on the valuation of landscape elements. Common to both studies is the positive willingness to pay for landscape preservation.

According to Drake (1992), there is a large difference in estimated value per ha depending on type of agricultural landscape, which in turn differs in different parts of Sweden. Dividing Sweden into three regions - Central, South, and North – he found that the WTP is higher in regions with relatively small area of land covered by agriculture. In the northern Sweden with relatively much forests, the WTP for agricultural landscape is thus highest and amounts in average to SEK 2149/ha. In the Central region the average WTP is SEK 1860/ha and lowest, SEK 1174/ha, in the South where most of the Swedish agricultural is located.

The investment value of agricultural landscape is found by multiplying the accounting price of agricultural landscape with regard to only its recreational values with the change in arable land. However, according to Drake (1992) WTP estimates of agricultural landscape may be over- or underestimated by 50 per cent. Recreational values are therefore calculated for these upper and lower bounds, se Table 3.

Table 3: Recreational values from Swedish agricultural landscape, billions of SEK in 2001 year prices.

Year	Area of arable land, 1000 ha[1]			Consumption value, bill SEK[2]		Change in arable land, 1000 ha			Investment value, bill SEK[3]		Total value	
	Cent	South	North	Low	High	Cent	South	North	Low	High	Low	High
2001	760	1645	274	1,97	7,30	-3	-7	-2	-0,21	-0,91	1,76	6,39
2000	763	1652	276	2,03	7,51	-8	-22	-12	-0,87	-3,34	1,16	4,17
1999	771	1674	288	2,09	7,71	-11	-17	-10	-0,72	-3,11	1,37	4,60
1998	782	1691	298	2,13	7,85	-2	-8	-3	-0,27	-0,98	1,86	6,87
1997	784	1699	301	2,14	7,88	-3	-7	-3	-0,25	-1,02	1,89	6,87
1996	787	1706	304	2,16	7,96	15	14	10	0,67	3,30	2,83	11,26
1995	772	1692	294	2,13	7,89	-3	-7	-3	-0,25	-1,02	1,88	6,87
1994	775	1699	297	2,20	8,12	-2	2	-1	0,00	-0,18	2,19	7,95
1993	777	1697	298	2,25	8,29	-3	6	1	0,14	0,18	2,39	8,48
1992	780	1691	297	2,35	8,67	-10	-11	-1	-0,28	-1,69	2,07	6,99
1991	790	1702	298	2,42	8,95	-26	-22	-5	-0,70	-4,32	1,73	4,63
1990	816	1725	303	2,70	9,97							

1. Swedish Board of Agriculture, 1990-2003
2. Mill SEK/ 1000 ha: Cent 0.93-2.79, South 0.59-2.61, North 1.08-3.22 in 2001 prices. Drake (1992)
3. Mill SEK/ 1000 ha: Cent 31-93, South 19-59, North 36-108 in 2001 prices

During the years under study, the average total value ranges from 1.16 to 11.26. The fluctuation is mainly due to the changes in area of arable land. Except for 1995, arable land shows a steady decline for all years except 1995 in all three regions. However, the increase in 1995 can be due to a change in the statistical measurement this year. From this year and on wards arable land now includes smaller farms than for previous years.

5. Wetlands

At a global scale, Sweden has one of the largest proportions of wetlands within its territory. Approximately 1/5 of total land is covered by wetlands. According to the Swedish EPA, wetland " …. is such land where water is, during a large portion of the year, just below, in line with, or just above the ground". Wetlands are among the most biodiversity rich ecosystems, and provide therefore a variety of ecosystem services (Mitsch and Gosselink, 1998). Examples of ecosystem services are recreational values, food, pollutant cleaning, and biodiversity. Since 1970s a number of wetland valuation studies have been made in different parts of the world. Recreational values and pollutant cleaning have mostly been valued. This is also the case for the six different studies valuing Swedish wetlands in monetary terms (Svensson, 2003). Subsequent calculation of the monetary value of changes in Swedish wetlands is based on these studies and also on Svensson (2003) for estimation of changes in wetland capital and impacts on ecosystem services.

During the period 1991-2001 there has been a net increase in the area of wetlands in the south of Sweden due to the subsidy payment by the Swedish Board of Agriculture and by municipalities. There has also been an ongoing degradation of wetlands from peat extraction and forest drainage in the northern parts. However, the provision of ecosystem services and, hence, their valuation is highly dependent on the location of the wetland site. Therefore, it might be misleading to simply value the net changes in wetland areas.

The six Swedish valuation studies have been made for wetlands in south Sweden. Four of them have estimated the value of wetland nitrogen abatement, which depends on the abatement capacity and costs of alternative abatement measures. Since nitrogen loads affect eutrophication in coastal waters of southern Sweden, it is simply assumed that this service is attributable only to the enlargement of wetlands in south Sweden, and not to the decline which is assumed to have occurred only in the north. Depending on wetland abatement capacity, alternative measures and abatement targets the abatement value range between SEK 500 and 75000 per ha and year. The lower value assumes cost savings of SEK 5/kg N abatement with a capacity of 100 kg abatement whereas the highest value assumes SEK 150/kg N abatement and an abatement capacity of 500 kg. Two Swedish wetland studies investigated other values of wetlands, which range between SEK 2500 and 16 051 per ha and year.

The consumption value is obtained by multiplying the area of wetlands with their unit values. The estimated consumption and investment values are then as presented in Table 4.

Table 4: Abatement and recreational values from Swedish wetlands, billions of SEK in 2001 year prices.

Year	Area of wetland, 1000 ha[1] South North	Consumption value, bill SEK[2]		Change in wetland area, 1000 ha South North	Investment value, bill SEK[3]		Total value	
		Low	High		Low	High	Low	High
2001	718 2970	9,58	113,23	0.68 -0.12	0,06	2,00	9,64	115,23
2000	718 2970	9,81	116,01	0.32 -0.48	-0,01	0,73	9,81	116,74
1999	717 2969	9,91	117,10	0.31 -0.49	-0,01	0,70	9,90	117,80
1998	717 2969	9,95	117,59	0.43 -0.37	0,01	1,15	9,96	118,74
1997	716 2969	9,94	117,37	0.39 -0.42	0,00	1,00	9,94	118,37
1996	716 2968	9,99	117,97	0.46 -0.34	0,02	1,27	10,01	119,23
1995	715 2968	10,04	118,49	0.46 -0.34	0,02	1,27	10,06	119,76
1994	715 2968	10,28	121,42	0.51 -0.29	0,03	1,50	10,31	122,92
1993	714 2967	10,49	123,84	0.51 -0.29	0,03	1,53	10,52	125,36
1992	714 2967	10,99	129,67	0.51 -0.29	0,03	1,60	11,02	131,27
1991	714 2966	11,24	132,70	0.1 -0.70	-0,06	-0,08	11,19	132,62
1990	714 2966	12,28	144,98	0.1 -0.70	-0,06	-0,09	12,22	144,89

1. Svensson (2003), Weisner et al. (2003), Lagerkvist (pers. comm), Hallbäcken (pers. comm)
2. Mill SEK/1000 ha: 0.5 and 75 for nitrogen abatement; 2.5 and 16.1 for recreation
3. Mill SEK/1000 ha: 16.7 and 2500 for nitrogen abatement; 83 and 537 for recreation

Due to the relatively small changes in wetland area, the investment values for all years are relatively low as compared to the consumption values. They correspond to at the most 1.7 per cent of the total value, which, in turn, varies between 9.6 and 144.9 billions of SEK depending on year and assumption of output values and wetland production of nitrogen abatement.

6. Urban systems

Urban systems are classified as ecosystems where the natural capital consists of green areas, water and air. Here, only air, or more precisely air quality, is included here. Further, value of changes in air quality only from deposition of nitrogen oxides is calculated. The direct impacts of air quality changes are those on human health. There are several air pollutants that can affect health. Huhtala and Samakovlis (2003) provides an example of how to value health impacts from nitrogen dioxide emissions in urban areas. The valuation of health effects is divided into two components: disutility from air pollution and productivity impacts.

Calculations are first related to a unit increase in the concentration of nitrogen dioxide and then translated to the yearly deposition in Sweden. According to Samakovlis et al (2003), a unit (μ/m^3) increase in the monthly average of nitrogen dioxide results in a 3 percent increase in respiratory-related restricted activity days (RRADs) in Sweden. This unit increase results in 885 727 extra RRADs per year in Sweden. Of these RRADs, 28 percent are so called minor RRADs lasting one day, and 62 percent are major RRADs. Transfer of results from international contingent valuation studies of willingness to pay to avoid the disutility for this amount of minor and major RRADs amount to SEK 498 millions. It is assumed that these estimates include only experienced discomfort and not labour productivity impacts. Assuming a linear relationship between deposition and concentration, the marginal disutility of health impacts amounts to SEK 18/kg NO_2.

Table 5: Value of health impacts from nitrogen dioxides in densely populated areas, in 2001 prices.

Year	NO2 dep. ton[1]	Disutility from health impacts[2]
2001	446 896	8.04
2000	469 898	8.67
1999	454 468	8.49
1998	423 236	7.96
1997	365 731	7.35
1996	391 691	7.45
1995	364 746	7.00
1994	433 752	8.39
19933	400 707	7.91
19923	425 434	8.79
1991	427 180	9.22

1. Ressner (2003)
2. Huhtala and Samakovlis (2002), Samakovlis et al. (2003)
3. Data was missing for these years, and depositions are therefore assumed to be proportional to GDP in 1991

Air quality is regarded as a stock variable, and changes in air quality thus show the change in air as a natural capital asset. However, the impacts on concentration of nitrogen dioxides of nitrogen deposition last only for one period, so the value of changes in air quality thus corresponds to the numbers presented in table 5. It would seem meaningless to try to calculate the consumption value of air quality, since this would imply the value of all human and non- human lives.

7. Sustainable use of Swedish natural capital

The sustainability criterion requires a non-negative change in natural capital during any period. Then, the production potential of the capital base is non-decreasing over the studied period. A sustainable change in wealth may thus include reductions in some capital stocks if this is compensated for by an increase in other resource stocks. When considering only natural capital, we allow for compensating increases for some declining assets only among the natural capital. The figures presented in Table 6, is thus only a partial estimate of sustainable change in wealth during the period.

Table 6: Changes in natural capital assets in Sweden during 1991-2001, billions of SEK.

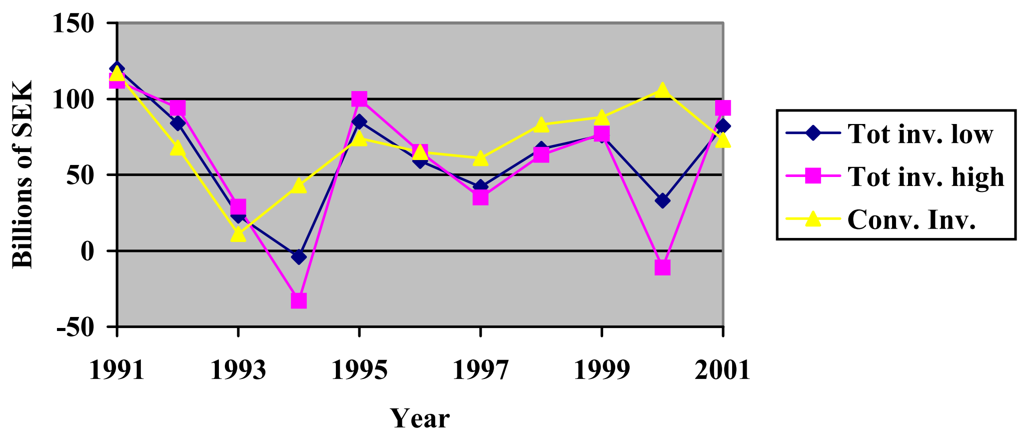
Year	Forest		Agric. landsc.		Wetlands		Urban	Total	
	Low	High	Low	High	Low	High		Low	High
2001	17,83	27,90	-0,21	-0,91	0,06	2,00	-8.04	9,64	20,95
2000	-63,50	-104,71	-0,87	-3,34	-0,01	0,73	-8.67	-73,05	-115,99
1999	-3,11	0,09	-0,72	-3,11	-0,01	0,70	-8.49	-12,33	-10,81
1998	-7,64	-12,35	-0,27	-0,98	0,01	1,15	-7.96	-15,86	-20,14
1997	-11,82	-19,21	-0,25	-1,02	0,00	1,00	-7.35	-19,42	-26,58
1996	0,69	3,42	0,67	3,30	0,02	1,27	-7.45	-6,07	0,54
1995	19,64	33,28	-0,25	-1,02	0,02	1,27	-7.00	12,41	26,53
1994	-38,22	-69,20	0,00	-0,18	0,03	1,50	-8.39	-46,58	-76,27
1993	19,90	24,39	0,14	0,18	0,03	1,53	-7.91	12,16	18,19
1992	24,87	35,02	-0,28	-1,69	0,03	1,60	-8.79	15,83	26,14
1991	12,99	8,67	-0,70	-4,32	-0,06	-0,08	-9.22	3,01	-4,95

Sources: Tables 1-5

According to Table 6, there is no sustainable use of any natural capital assets. On the contrary, all assets except for wetlands, show a net decline during the studied period. The accumulated net change during the 10 years of all assets included in table 6 is either approximately -120 or -163 billions of SEK depending on the assumed values of ecosystem services.

The change in natural capital assets can be relatively high as compared to conventional net investment. When adjusting conventional net investment with the net investment in natural capital as presented in table 6, the total net investment may turn into a negative number, see figure 1.

Figure 1: Total investment for low and high monetary values of ecosystem services, and non- adjusted investment



Source: Tables 6 and A1

During the first two years, total investment is slightly larger than conventional due to the positive net investment in natural capital as shown in table 6. However, during 1993 conventional investment is increasing while the adjusted is decreasing and may become negative in 1994. These opposite directions of investment are also true for the year 1999. In 2000, the opposite relation is the case. Then conventional investment is decreasing and adjusted investment is increasing. This year also shows the largest differences between conventional and adjusted investment. The accumulated conventional investment is 18 per cent or 26 per cent larger than the adjusted investment with low respectively high values of ecosystem services.

It should be kept in mind, however, that only a fraction of ecosystems and their services are included in the calculations. Furthermore, strong assumptions underlie the calculations that are made and calculated value may be an underestimate for forests and agricultural landscape since only part of the value of the replaced areas are included. Conversion of land into wetlands, and from forests into agricultural land and vice versa is accounted for, but not other type of land conversions. On the other hand, overestimates are made due to the lack of ecosystem management costs.

8. Natural capital and growth

Growth is here measured as change in net domestic product (NDP). The correction of conventional NDP is made with respect to the investment and consumption estimates as presented in Tables 1-6, see table 7.

Table 7: Consumption of non-market goods and consumption plus investment values, in billions of SEK, and per cent of NDP.

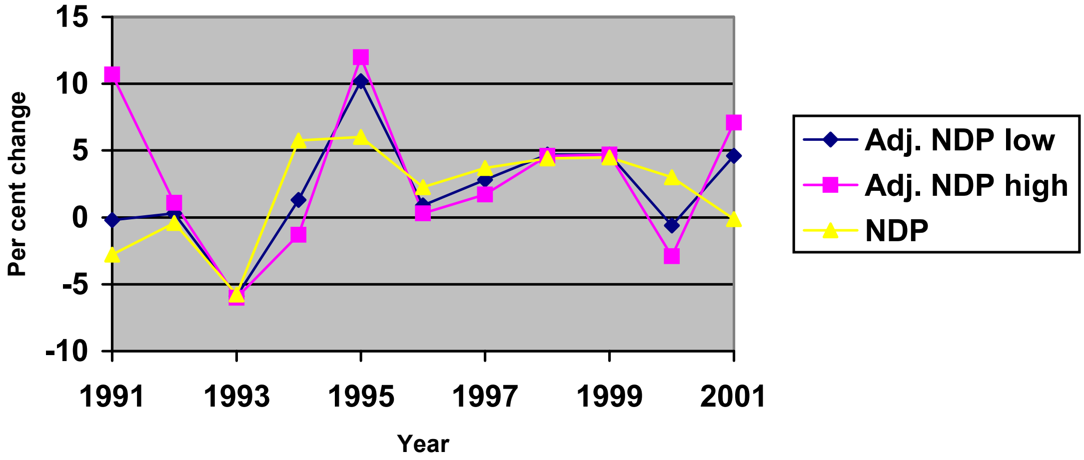
Year	Consumption; Forest		Agric. land		Wetlands		Tot cons plus investment		Per cent of conven. NDP	
	Low	High	Low	High	Low	High	Low	High	Low	High
2001	18,82	56,02	1,97	7,30	9,58	113,23	40,01	197,5	2,18	10,75
2000	17,03	53,84	2,03	7,51	9,81	116,01	-44,18	61,37	-2,40	3,34
1999	19,53	58,22	2,09	7,71	9,91	117,10	19,2	172,22	1,07	9,64
1998	18,38	56,36	2,13	7,85	9,95	117,59	14,6	161,66	0,85	9,45
1997	16,35	53,14	2,14	7,88	9,94	117,37	9,01	151,81	0,55	9,27
1996	16,88	54,13	2,16	7,96	9,99	117,97	22,96	180,6	1,45	11,44
1995	18,94	57,46	2,13	7,89	10,04	118,49	43,52	210,37	2,82	13,62
1994	18,16	56,84	2,20	8,12	10,28	121,42	-15,94	110,11	-1,09	7,56
1993	19,87	60,41	2,25	8,29	10,49	123,84	44,77	210,73	3,25	15,30
1992	20,88	63,59	2,35	8,67	10,99	129,67	50,05	228,07	3,42	15,60
1991	22,34	66,75	2,42	8,95	11,24	132,70	39,01	203,45	2,66	13,86

Sources: Tables 1-6 and A1 in appendix

For most of the years, there is a net increase in NDP when adjusting for consumption and investment values from natural capital. At the most, the adjustment implies an increase by approximately 16 per cent. In the case of low values of environmental services, there is a net decrease, at the most by 2.4 per cent.

When comparing growth in conventional NDP with that in the adjusted NDP, significant difference can be observed, see Figure 2.

Figure 2: Annual growth in NDP and adjusted NDP for low (NDPl) and high (NDPh) values of environmental services



Source: Table 7 and Table A1 in appendix

There are relatively small differences between growth in adjusted and non-adjusted NDP for half of the period: 1992, 1993, 1996-1999. On the other hand, there are significant differences for the other years. Between 1990 and 1991, adjusted NDP with high values of ecosystem services is decreasing, and the non-adjusted NDP increasing, and between 2000 and 2001 both adjusted NDPs are increasing and non-adjusted NDP is decreasing. For both these periods, the differences in growth can be higher than five per cent units. The pattern is the same when adjusting both types of NDP with respect to population change, see figure A1 in the appendix.

Except for the capital asset Urban systems, all values presented in table 6 can be attributed to the agriculture and forest sectors. The value added of these two sectors varies between 34.8 and 44.9 between 1991 and 2001 (Swedish Statistics, 1980-2003). The estimated values of the non-marketed recreational values and pollutant sequestration can then be significant as compared to the contribution of the marketed goods and services. This result is in line with several other studies valuing non-market output from the forest and agricultural sectors, which show that the value of these output is about 70 to 80 per cent of the sectors' value added (Turner et al. 2003).

The empirical results presented in Table 7 and Figure 2 differ from other corrections of Swedish NDP, which instead result in a decline of NDP (Ahlroth, 1997; Skånberg 2001). This is due to the difference in focus, which in Ahlroth and Skånberg as well as in many other empirical studies is on pollutant emission, which enters directly into the utility function. The negative impact on utility from pollutants is then subtracted from conventional NDP. This paper also allows for a negative impact on utility from pollutant, i.e. health impacts of nitrogen dioxide deposition, but the main focus is on ecosystems as inputs in production of ecosystem services. This generates a positive utility from production of non-marketed ecosystem services, which increases conventional NDP. Pollutants can reduce the ecosystems' production capacity, but ecosystem service production must not be negative. Negative impacts on NDP from pollution then occur only from disinvestment in natural capital.

9. Summary and conclusions

The purpose of this paper has been to measure the non-marketed value of changes in Swedish natural capital assets. A specific feature of this paper is the approach with a direct focus on ecosystems as natural capital assets, which, in turn, are regarded as inputs into production of ecosystem services. Consumption and investment values of natural capital were derived from its current and future streams of ecosystem services. The estimates have then been used to assess sustainability in Sweden, which is obtained from net investment of natural and produced capital. Furthermore, growth as measured by annual net change in net domestic product has been calculated with the inclusion of non-marketed ecosystem services.

Not surprisingly, however, the estimation of values of natural capital changes through their provision of ecosystem services turned out to be associated with considerable empirical challenges. The problem of finding values of non-marketed goods and services have been known and also investigated since 1970s. Estimation of accounting prices also requires the quantification of the relation between production of outputs and natural capital stock levels, which showed to be the most difficult task for the calculation of Swedish accounting prices on forests, wetlands, agricultural landscape, and urban systems. The estimates were based on the availability of existing valuation studies of ecosystem services. Therefore, two outputs – recreational values and pollutant sequestration – were included.

Given all caveats associated with finding data, the net result points at an unsustainable use of the ecosystems under the years of study. The net investment in natural capital varies between –116 and 27 billions of SEK depending on assumption of unit values of ecosystem services and year of study. This can be compared with net investment as measured by national accounts, which range from 11 to 156 billions of SEK during the same years. Correcting conventional investment with that in natural capital can either increase or decrease total investment, and even result in a negative net investment. On the other hand, the correction of NDP implies an increase for all years except one. The non-marketed services may increase conventional NDP by 16 per cent. It was also shown that conventional and adjusted NDP may change in different directions. The difference in growth rates can be 10 per cent units for relatively high valuation of ecosystems' production of ecosystem services.

The empirical demonstration clearly pointed at the difficulties in finding appropriate data, in particular on the relations between natural asset status and production of ecosystem services. These relations are characterised by spatial and dynamic heterogeneity, which, however, is true also for many marketed goods and services. Although there is currently much less information on the shape of production function for ecosystem services than for marketed goods, this lack of data could in principle be reduced by use of statistical methods.

Such methods have been applied during decades for estimating market goods production functions. This would imply a focus on ecosystem services as outputs with various ecosystems as inputs. Most of the valuation literature so far has the reverse focus, i.e. on the valuation of ecosystems. Although results from such studies have been used for the empirical demonstration in this paper, it is difficult to obtain information on substitution or complementary impacts among ecosystems in producing similar types of outputs, such as recreational values.

In spite of the difficulties of finding adequate data, the approach suggested in this paper still implies simplified empirical calculations as compared to a focus on pollution or waste from the production and household sectors. The latter is used in much practical green accounting systems, see for example Eurostat, 2003. When the aim of the green accounting is to measure changes in well being, the ecosystem approach requires information on production functions for ecosystem services and their values. The pollution approach will also need this data, but in addition requires information on the impact of pollution on ecosystem functioning. In small countries like Sweden, this can be quite challenging since most of the pollution emissions are widespread and deposited outside the national territory.

References

Ahlroth, S. (1997). Correcting net domestic product for sulphur dioxide and nitrogen oxide emissions: Implementation of a theoretical model. Working Paper No. 73, National Institute of Economic Research, Stockholm.

Aniar, S. (2002). Estimating an economic indicator of sustainability for the Venezuela and Norwegian economies. Manuscript, Beijer International Institute of Ecological Economics, Stockholm.

Arrow, K., Dasgupta, P. and K-G Mäler, (2002). Evaluating projects and assessing sustainable development in imperfect economies. Manuscript, Beijer International Institute of Ecological Economics, Stockholm.

Byström O. (1998). Byström, O. (1998). The nitrogen abatement cost in wetlands. Ecological Economics 26:321-331.

Daily, G. (ed.), (1997). Nature's services: Societal dependence on natural ecosystems. Island Press, Washington DC.

Dasgupta, P. and K-G. Mäler, (2000). Net national product, wealth and social well-being. Environment and Development Economics 5:69-93.

Dasgupta, P. and K-G. Mäler, (2001). Wealth as a criterion for sustainable development. World Economics 2(3):19-44.

Drake, L. (1992). The non-market value of the Swedish agricultural landscape. European Review of Agricultural Economics 126(1):75-86.

European Commission, (2000). Green paper on greenhouse gas emissions trading within the European Union. COM(2000)87 final (presented by the Commission).

Fenech, A., Foster, J., Hamilton, K., and R. Hansell (2003). Natural capital in ecology and economics: An overview. Environmental Monitoring and Assessment 86:3-17.

Forsgren, A. 2003. Analys av växthusgaser, SEPA (Swedish Environmental Protection Agency), Department of transport and energy, Stockholm, mimeo.

Gren, I-M. (2003). Ecosystem services and green national accounts. Working paper 86, Swedish National Research Institute, Stockholm.

Gylfasson, T. (2001). Natural resources , education, and economic development. European Economic Review 45:847-859.

Hamilton, K. and M. Clemens, (1999). Genuine saving rates in developing countries. World Bank Economic Review 13(1):336-56.

Hartwick, J. (2001). National accounting with natural and other types of capital. Environmental and Resource Economics 19:329-341

Hasund, K P. 1998. Valuable Landscapes and Reliable Estimates. In The Economics of Landscape and Wildlife Conservation. (ed. Dabbert, S.) Wallingford: CAB International

Heal, G., and B. Kriström, (2001). Green accounting. Manuscript, Department of Forestry Economics, SLU, Umeå.

Huhtala, A., and E. Samakovlis (2003). Green Accounting, Air Pollution and Health.Manuscript, National Institute of Economic Research, Stockholm.

Hultkrantz, L. (1992). National account of timber and forest resources in Sweden. Environmental and Resource Economics 3:284-305.

Jämttjärn, J. (1996). Recreational values of Swedish forests. (in Swedish). National Institute of Economic Research, Stockholm, mimeo.

Mitsch, W. and J. G. Gosselink, (1993). Wetlands. 2nd ed. New York: Van Nostrand Reinhold.

National Board of Forestry, Annual Statistics of Forestry 1990-2003, Jönköping Sweden.

Olsson, M. (2003). Svensk miljövervakning måste mäta kolförråd. Miljötrender Nr 3(03):8-11. Tema: Skogsbruk och växhusgaser.

Perman , R. Ma, Y. McGilvary, J. and M. Common, (2003). Natural resources and environmental economics. Pearson Education Limited, Harlow, UK.

Ramsey, F.P. (1928). A mathematical theory of saving. Economic Journal 38: 543-59.

Sachs, J. and A. Warner, (2001). Natural resources and economic development. The curse of natural resources. European Economic Review 45:827-838.

Samakovlis, E., A. Huhtala, T. Bellander and M. Svartengren (2003). Air Quality and Health

Dose-Response Relationships for Sweden. Manuscript, National Institute of Economic Research, Stockholm.

Skånberg, K. (2001). Constructing a partially environmentally adjusted net domestic product for Sweden 1993-1997: A presentation of the methodological steps and empirical data. National Institute of Economic Research, Working paper, Stockholm

Swedish Board of Agriculture, Statistic Yearbook of Agriculture 1990-2003, Jönköping, Sweden.

Swedish Statistics, 1980-2003. Nationalräkenskaper 1980-2003. Statistics Sweden, Stockholm

Sundberg, S. and T. Söderqvist, (2004). A survey of Swedish environmental valuation studies. Occasional paper series, Beijer International Institute of Ecological Economics, Stockholm, Sweden.

Svensson, L. (2003). Swedish wetland values. Manuscript, National Institute of Economic Research, Stockholm, Sweden.

Turner, R.K., Paavola, J., Cooper, P., Farber, S., Jessamy, V., and S. Georgiou. 2003. Valuing nature: lessons learned and future research directions. Ecological Economics 46:493-510.

United Nations, (2002). Integrated economic and environmental accounting, United Nations.

Weisner, S., Svensson, J., Strand J., and G. Sahlén (2003). Utvärdering av våtmarker med jorbruksstöd respektive lokala investeringsprogram. Steg 1: insamling och sammanställning av datamaterial för steg 2-4. Våtmarkskcentrum, Högskolan i Halmstad, Sweden.

Weitzman, M. (2001). Gamma discounting. American Economic Review 91(1):260-71.

Vincent, J.R.(2001). Are greener national accounts better? CID Working Paper No. 63, Harvard University.

World Commission on Environment and Development, (1987). Our common future. The Brundtland Report. Oxford University Press.

Östblom, G. (1999). An environmental medium term economic model – EMEC. Working Paper No. 69, National Institute of Economic Research, Stockholm, Sweden.

Web pages:

Eurostat, 2003, http://www.eurostat.eu.in

SLU, 2003. http://www.slu.se/riksskogstaxeringen

Personal communication

Hallbäcken, L. Miljödata, Swedish University of Agricultural Sciences, Uppsala, Sweden. December 16, 2002.

Lagerkvist, N. Swedish Board of Agriculture, Jönköping, Sweden. May 26, 2003.

Ressner, E. Swedish Meteorological and Hydrological Institute (SMHI), Norrköping, Sweden. December 3, 2003.

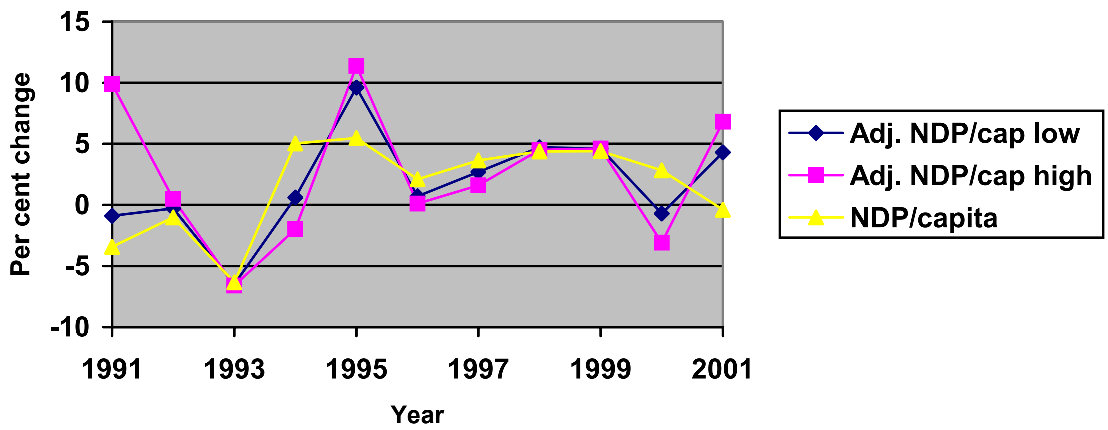
Appendix: Table A1 and figure A1

Table A1: GDP, depreciation, population, NDP and NDP/capital

Year	GDP, SEK 10^9	Gross investment, SEK 10^9	Depreciation, SEK 10^9	CPI, inverted	Pop. 10^3	NDP in 2001 prices SEK 10^9	NDP/ capita SEK 10^5
2001	2167	402	329	1	8 896	1838	0,20661
2000	2099	406	303	0,976	8 872	1840,164	0,207413
1999	2005	364	279	0,966	8 858	1786,749	0,20171
1998	1905	340	260	0,962	8 851	1709,979	0,193196
1997	1824	306	247	0,963	8 846	1637,591	0,185122
1996	1752	301	239	0,958	8 841	1579,332	0,178637
1995	1706	304	234	0,953	8 827	1544,596	0,174985
1994	1587	272	232	0,93	8 781	1456,989	0,165925
1993	1482	237	227	0,911	8 719	1377,607	0,158001
1992	1488	275	216	0,87	8 668	1462,069	0,168674
1991	1463	314	215	0,85	8 617	1468,235	0,170388
1990	1377	323	202	0,778	8 559	1510,283	0,176456

Sources: Statistics Sweden, 1980-2001

Figure A1: Annual growth in NDP/capita and adjusted NDP/capita for low and high values of ecosystem services



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