Socio-Economic Costs from Yellow Dust Damages in South Korea*

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Abstract: Yellow dust is a typical transborder environmental problem in Asia. South Korea is geographically very close to the place where yellow dust originates. This makes South Korea more than other countries susceptible to the damage from yellow dust. Most research on yellow dust has been done by natural scientists, focusing on the analysis of chemical constituents of yellow dust and its impact on the quality of water, air, soil, animal, and human health. In addition, quite some research has been done on the socio-economic impact of yellow dust. With such implications, the objective of this paper is to estimate the socio-economic cost from yellow dust in South Korea. The total socio-economic cost from yellow dust damage in South Korea in the year of 2002 is estimated as US$ 3,900 million at minimum and US$ 7,300 million at

Key words: Transborder Environmental Problem, Yellow Dust, Input–Output Analysis, Integration of Environmental–Economic Evaluation Technique, Contingent Valuation Method, Bottom–Up Approach, Benefit Transfer Method

* This paper was presented at International Symposium Transborder Environmental and Natural Resource Management organized held in Kyoto, Japan on December 5-7, 2007. The symposium was organized by The Center for Integrated Area Studies (Kyoto University), and the Center for Environmental Sciences (Leiden University, The Netherlands). The author wishes to acknowledge the three anonymous peer-reviewers for their valuable comments on the draft of this paper.

Korean Social Science Journal, XXXV No. 2(2008): 1~29.

maximum. The average of the two, US$ 5,600 million, is equivalent to 0.8% of GDP and US$ 117.00 per South Korean inhabitant.

Ⅰ. Introduction

The implication of environmental problems are very wide, but the issue can be converged into the depletion of resources, pollution and/or the destruction of the original quality of nature, and as a result, a threat to the self-regulating mechanism of nature (Jeong, 2000: 163). Environmental problems occur locally, but their impact may be global. In this sense, some environmental problems such as climate change, ozone depletion, and acid rains are termed transborder environmental problems. Goldblatt (1997) argues that such a transborder situation is the globalization of environmental problem.

Yellow dust, which is also termed Asian dust, yellow sand, yellow wind, or China dust storm, is a typical transborder environmental problem in Asia. It is a seasonal meteorological phenomenon which affects much of East Asia sporadically during the springtime months. The dust originates in the deserts of Mongolia and northern China and Kazakhstan where high-speed surface winds and intense dust storms kick up dense clouds of fine, dry soil particles. These clouds are then carried eastward by prevailing winds and pass over China, North and South Korea, and Japan, as well as parts of the Russian Far East. Sometimes, the airborne particulates are carried much further, in significant concentrations that affect air quality as far east as the United States. In the last decades or so, it has become a serious problem due to industrial pollutants and intensified desertification in China, but also in the last few decades when the Aral region of Kazakhstan dried up due to a failed Soviet agricultural scheme.

A lot of research on the impact of yellow dust as a transborder environmental problem has been done in South Korea, Japan, and Taiwan. Most research has been done by natural scientists, focusing on the analysis of chemical constituents of yellow dust and its impact on the quality of water, air, soil, animal, and human health (e.g. Kwon et al., 2002; Yabe et al., 2003; Wang et al., 2004; Ichinose et al., 2005; Kang and Lee, 2005; Okuda et al., 2005; Lee et al., 2006). In addition, quite some research has been done on the socio-economic impact of yellow dust.

South Korea is geographically very close to the place where yellow dust originates. This makes South Korea more than other countries susceptible to the damage from yellow dust. The objective of this paper is to estimate the socio-economic cost from yellow dust in South Korea. The paper will explain first how often yellow dust has occurred per year during the past decade. Second the paper introduces the methods used to estimate the socio-economic cost of yellow dust. Third, this socio-economic cost will actually be estimated. Finally, as a conclusion, the paper will examine the implications of the estimation techniques and the estimated socio-economic cost.

Ⅱ. The Yellow Dust Phenomenon

1. A Historical Record

The first record of yellow dust is from the Silla Dynasty in 174. Yellow dust was called soil rain, and the people believed that God had become so angry that he lashed down dirt instead of rain or snow. The following record is from the Baekje Dynasty in April 379: “Dust fell all day long.” An additional record from March 606 states that the sky of the Baekje’s capital was darkened like night by falling dust.

Although these dust phenomena mainly occur during springtime, some records mention occurrences in winter as well. During the Goguryeo Dynasty in October 644, it was recorded that there was a red snow that fell from the sky, suggesting that yellow dust had mixed with snow at the time. The definition of the yellow dust event was introduced in the reign of Gorye as follow: “There was dirt on clothes without getting wet by rain.” Hence it was called soil rain.

During the Yi Dynasty, on March 22, 1549 the following notes were recorded: “Dust fell in Seoul. At Jeonju and Namwon in the Jeonla province, located in the southwestern part of Korea, there was a fog that looked like smoke creeping into every corner in all directions. The tiles on the house roof, grasses and tree leaves were entirely covered by yellow-brown and white dusts. When the dust was swept, it wiped away like dirt, and when it was shaken, it dispersed, too. This weather condition lasted until March 25, 1549.”

2. The Frequency of Yellow Dust

South Korea’s Government runs 22 observation sites throughout the whole country to measure yellow dust. Table 1 shows the frequencies of yellow dust occurrence from 1997 to 2006 in seven major cities (MOESKG, 2007).

Table 1. Frequencies of Yellow Dust Occurrence 1997 - 2006 in Major Cities

City \ Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Seoul	1	3	3	6	7	7	2	4	9	7
Gangnung	1	2	1	3	7	6	2	3	3	6
Daejeon	1	3	2	4	7	6	2	6	5	6
Daegu	1	2	2	5	8	5	2	5	3	7
Jeonju	1	2	1	6	10	6	1	6	5	4
Gwangju	1	2	2	6	7	6	1	6	5	5
Busan	1	2	1	6	8	5	0	4	2	6

As shown in Table 1, the frequencies of yellow dust occurrence during the past ten years show a fluctuation from 1996 to 1997 in all the seven cities, but tends increase since 2000 except 2003. The frequencies were not singificantly different among the cities during that period except Jeju in 2001 and Seoul in 2005.

The days of yellow dust occurrence have increased every year (MOESKG, 2007). For example, its average was 3.9 days in the 1980s, 7.7 days in the 1990s, and 12.4 days since 2000. The maximum density has also increased every year (MOESKG, 2007), from 356μg/m3 in 2000, to 600μg/m3 in 2003, and 2,941μg/m3 in 2006. Spring is the main season yellow dust occurs but since 2000, yellow dust also occurs in winter.

Research has shown that the increase in the frequency and density of yellow dust in South Korea are related to the high atmospheric pressure in Siberia and the temperature in the Northern hemisphere (Kim and Lee, 2006). Yellow dust days show negative correlation with Siberian high atmospheric pressure in February and March. When Siberian high atmospheric pressure becomes weak in spring, the possibility of yellow dust occurrence becomes high. Meanwhile, yellow dust days had a positive correlation with monthly average temperatures of the Northern hemisphere, especially, in the case of strong yellow dust days. Global warming, therefore, might positively affect the occurrence of strong yellow dust days.

Ⅲ. Estimation Methods of Socio-Economic Costs

1. Input-Output Analysis (IOA)

IOA is one of a set of related methods that show how all the parts of a system are affected by a change in one part of that system (OECD, 2006: 7-8). IOA is used, for instance to show industries and their input and output links. For example, in the case of coal and steel producing industries, while coal is required to produce steel, some amount of steel in the form of tools is also required to produce coal. Hence, IOA is a tool of applied equilibrium analysis. IOA is widely used in economic forcasting to predict the effect of changes in one industry on others, or to predict changes among consumers, government, and foreign suppliers in a particular economy. IOA can be applied to estimate the socio-economic cost from yellow dust by evaluating both tangible and intangible socio-economic impacts of yellow dust at regional and/or national level.

Some scholars have applied IOA to the analysis of environmental problems like energy flows and air pollutants (e.g. Hayami and Kiji, 1997), the economic costs from yellow dust (e.g. Ai and Polenske, 2005), and the emission of CO2and greenhouse gases (e.g. Hayami et al, 1997 OECD, 2006: 29-32).

Applying IOA to estimate the economic cost of yellow dust is appropriate given that decreased demand from affected sectors (e.g. households) may diminish production in other sectors and analysts may trace the demand-driven effects on a region's and/or a country's output by the changes in final demand.

2. Integration of Environmental-Economic Evaluation Technique (IEEET)

IOA can't capture all the economic impacts of yellow dust, because some sectors apparently affected by yellow dust may not change the demand from other industries. IEEET is a technique for capturing non-economic or environmental aspects of yellow dust (for details, see Ai and Polenske, 2005). IEEET includes Dose-Response Analysis (DRA), Market-Value Method (MVM), and Human-Capital Method (HCM). DRA is a component of risk assessments that describe the quantitative relationship between the amount of exposure to a substance and the extent of toxic injury or disease caused by such a substance. Hence, DRA estimates the number of people affected and corresponding workday losses by examining the change in the concentration of toxicity during yellow dust. MVM evaluates economic impacts by multiplying the losses in productivity by the market value. HCM ascribes a money value to the health impacts on working people exposed to environmental pollution. Thus, applying HCM to yellow dust, it is possible to measure the economic losses of workdays interrupted during yellow dust.

Synthesizing DRA, MAV, and HCM, we firstly rely on dose-response functions to estimate the total number of workday losses. Then we multiply the result by the value that the workers would have produced per day if yellow dust had not occurred, using gross domestic product per capita per day as a substitute.

3. Contingent Valuation Method (CVM)

CVM is a survey-based economic technique for the valuation of non-market resources such as environmental preservation or the impact of contamination (Carson, 2000; Groothuis, 2005; Kimenju, 2005). While these resources do give people utility, certain aspects of them do not have a market price as they are not directly sold – for example, people receive benefit from a beautiful view of a mountain, but it would be tough to value using price-based models (Kim, 2002).

CVM refers to the method of valuation used in cost-benefit analysis and environmental accounting. It is conditional (contingent) on the construction of hypothetical markets, reflected in expressions of the willingness-to-pay for potential environmental benefits or for the avoidance of their loss. Thus, CVM is a method of estimating the value that a person places on a good in hypothetical situations. The approach asks people to directly report their willingness-to-pay (WTP) to obtain a specified good, or willingness-to-accept (WTA) to give up a good, rather than inferring them from observed behaviors in regular market places (Frykblom, 2000; Ryan and Miguel, 2000 Goldar and Misra, 2001; Venkatachalam, 2004). Where CVM is applied to environmental problems, through a questionnaire the hypothetical situations are presented to a representative sample of the relevant population in order to elicit statements about how much they are willing to pay for a benefit and/or willing to accept in compensation for tolerating a cost.

The main stages in the application of CVM are as follows. (1) Define the good and the change in the good to be valued. (2) Define the geographical scope of the market. (3) Set up the hypothetical market. (4) Conduct focus groups on components of the survey. (5) Conduct a pretest of the survey instrument (questionnaire). (6) Conduct a sample survey. (7) Calculate average WTP or WTA. (8) Estimate bid curves and (9) evaluate the CVM exercise.

There are a number of techniques that have been used in the CVM to estimate the non-marketed value of any specific environment amenity or scenic resources. These include direct cost, revealed demand and bidding game. Direct cost is a method of estimating the non-marketed benefit of reduced environmental damage based on direct estimate of the cost to be projected from that damage (Randal et al., 1994). Revealed demand is a technique to infer the non-marketed benefit from the revealed demand for some appropriate proxy. In the case of reduced air pollution, the revealed demand for residential land is related to the concentration of air pollution (Randal et al., 1994). Bidding game is also a technique of estimating the non-market benefit of improved environmental quality or establishment of recreation sites (Knetsch and Davis, 1966).

Like other research techniques, CVA has some methodological problems (for details, see Venkatachalam, 2004; Andersson and Svensson, 2006). However, CVA is applied to a wide range of empirical research. The examples include yellow dust (e.g. Hong, 2004; Kang et al., 2004; Ai and Polenske, 2005), climate change (e.g. Berk and Fovell, 1999), ozone pollution control policy (e.g. Yoo and Chae, 2001), ecosystem services (e.g. Loomis, 2000), biodiversity (e.g. Macmillan et al., 2001), endangered species (Kotchen and Reiling, 2000), health care (Bonato et al., 2001; Johannensson, 2006), clean air (e.g. Belhaj, 2003), and water resources (e.g. Phuong and Gopalakrishnan, 2003).

4. Bottom-Up Approach (BUA)

Top-Down and Bottom-Up approaches are strategies of information processing and knowledge ordering, mostly involving software, and by extension other humanistic and scientific system theories. The two approaches are applicable to wider ranges of humanistic and scientific system theories than the techniques explained above.

In a top-down approach an overview of the system is first formulated, specifying but not detailing any first-level subsystems. Each subsystem is then refined in yet greater detail, sometimes in many additional subsystem levels, until the entire specification is reduced to base elements. Top-down model is often specified with the assistance of 'black boxes'that make it easier to manipulate. However, black boxes may fail to elucidate elementary mechanisms or be detailed enough to realistically validate the model.

In a bottom-up approach the individual base elements of the system are first specified in great detail. These elements are then linked together to form larger subsystems, which then in turn are linked, sometimes in many levels, until a complete top-level system is formed. This strategy often resembles a 'seed'model, whereby the beginnings are small, but eventually grow in complexity and completeness.

For example, the bottom-up approach focuses on a specific company rather than on the industry in which that company operates or on the economy as a whole, and assumes that individual companies can do well even in an industry that is not performing very well. Applying such bottom-up approach to the socio-economic cost from yellow dust, all the areas and items damaged from yellow dust are listed, and their costs are estimated, and then are summing up (Kang et al., 2004: 28).

The bottom-up approach also has some limitations that: BUA is usually formulated without explicit reference to an economic scenario. Moreover, where tests rely on historical events, BUA may not capture effectively the future changes in the economic environment that will affect the portfolio performance. The use of sophisticated modeling techniques could also create a false scene of security and complacency without a thoughtful analysis of current and prospective economic conditions.

5. Benefit Transfer Method (BTM)

Increased use of economic analyses in environment, transport, energy, health and cultural sectors has increased the demand for information on the economic value of environmental and other non-market goods by decision-makers. Due to limited time and resources when decisions have to be made, new environmental valuation studies often can't be performed, and decision makers must rely on transfer of economic estimates from previous studies (often termed 'study sites') of similar changes in environmental quality to value the environmental change at the 'policy site'. This procedure is most often termed 'benefit transfer', but damage estimates can also be undertaken (Groothuis, 2005).

Benefit transfer is a pragmatic way of estimating values for environmental or social tradeoffs when there is limited time or funding available, and BTM is used to estimate economic values for ecosystem services by transferring available information from studies already completed in another location and/or context. However, the term 'benefit transfer' is normally used to identify the transfer of non-market values from source studies to a target site. Thus, the basic goal of benefit transfer is to estimate benefits for one context by adapting an estimate of benefits from some other context.

BTM was developed as an alternative way to value externalities using values from studies of similar circumstances, carried out at similar sites somewhere else, given the challenges and high costs inherent in assessing the actual cost. Four BTMs have been developed. They are benefit estimate transfer, benefit function transfer, meta-analysis, and preference calibration (Groothuis, 2005). Benefit estimate transfer is the simplest; it is when researchers obtain a benefit estimate from one study and transfer the estimate directly to the policy site on the basis of mean 'willingness-to-pay'/household/year. This approach is based on 'the unit day approach' where existing values for activity days are used to value the same activity at other sites, and assumes that the well-being experienced by an average individual at the study site is the same as will be experienced by the average individual at the policy site.

Benefit function transfer and meta-analysis, which use only one study, but more information is effectively taken into account during the transfer, employing statistical models from existing studies while using policy information to control differences between the study site and the policy site. The main difference between benefit function transfer and meta-analysis is that the former transfers a valuation, allowing adjustment for variety of site differences, while the latter combines the results of several studies to generate a pooled model. Preference calibration, on the other hand, uses existing benefit estimates derived from different methodologies and combines them to develop a theoretically consistent estimate for the policy site.

Brouwer (2000) proposes a detailed seven-step protocol as a first attempt towards good practice for using BTM. The steps may be generalized as follows. Step 1 is to identify existing studies or values that can be used for the transfer. Step 2 is to decide whether the existing values are transferable. Step 3 is to evaluate the quality of studies to be transferred. The better the quality of the initial study, the more accurate and useful the transferred value will be. This requires the professional judgment of the researcher. Step 4 is to adjust the existing values to better reflect the values for the site under consideration, using whatever information is available and relevant. The researcher may need to collect some supplemental data in order to do this well. For example, the sites valued in each of the existing studies differ from the site of interest. The researcher might adjust the values from the first study by applying demographic data to adjust for the differences in users. If the second study has a benefit function that includes the number of substitute sites, the function could be adjusted to reflect the different number of substitutes available at the site of interest.

Like other research techniques, BTM has advantages and limitations. Its major advantages are (Ruijgrok, 2001; Groothuis, 2005; Ready and Navrud, 2006): (1) BTA is typically less costly than conducting an original valuation study (2) economic benefits can be estimated more quickly than when undertaking an original valuation study and (3) BTM can be used as a screening technique to determine if a more detailed, original valuation study should be conducted.

However, transfer processes can be complex to avoid potential sources of error in the extrapolation of values to sites or issues of interest. In relation to the potential sources of error, the major limitations of BTM are summarized as follows (Ruijgrok, 2001; Groothuis, 2005; Ready and Navrud, 2006): (1) Benefit transfer may not be accurate, except for making gross estimates of values, unless the sites share all of the site, location, and user specific characteristics. (2) Good studies for the formulation of policies may not be available. (3) It may be difficult to track down appropriate studies, since many are not published. (4) Reporting of existing studies may be inadequate to make the needed adjustments.

A lot of empirical research has been done, applying BTM to environmental contexts. Recent applications include Rozan (2004) on improved air quality in France and Germany, Muthke and Holm-Mueller (2004) on national and international transfers of water quality improvement benefits, Jiang et al. (2005) on coastal land management, Colombo, Eshet et al.(2006) on disamenities of waste transfer stations in Israel, and Colombo et al. (2007) on the off-site impacts of soil erosion.

As is identified from the above explanation, the five estimation methods have advantages and disadvantages in the estimation of socio-economic costs damaged from yellow dust. They are compared as below.

IOA is an appropriate method in tracing the demand-driven effects on a region's and/or a country's output by the changes in final demand. However, IOA can't capture all the economic impacts, because some sectors apparently affected by yellow dust may not change the demand from other industries. IEET has an advantage for capturing non-economic or environmental aspect of yellow dust, but is weak in exact estimation of basic data such as productivity by market value, environmental pollution, and total number of workday losses, etc. CVM has an advantage in that it can be applied to wide ranges such as yellow dust, climate change, and ecosystem services, etc. However, the main disadvantage of CVM is that it is a survey-based technique which has a possibility to collect a partial data. BUA enables us to cover all the areas and items damaged from yellow dust, but has a major disadvantage in that it may not capture effectively the future changes in the economic environment. BTM's major advantage is that it is a pragmatic way of estimating values for environmental or social tradeoffs when there is limited time or funding available. However, the major advantage is BTM is how to control the possible error in the estimation arisen from extrapolation of values to sites or issues of interest.

Ⅳ. Socio-Economic Costs from Yellow Dust

It is known that 20 million tons of yellow dust is generated from the place of origin every year, and 5.50 - 9.50 million tons are brought in by air into the Korean peninsula. Yellow dust impacts negatively on nature, society, and human healthy (UNEASC, 2004). Recent research has identified that yellow dust has some positive impacts on nature (Hong, 2004; Ai and Polenske, 2005; NIESKG, 2007), because it absorbs solar radiation and off-sets global warming, prevents the red tide through the neutralization of sea water, neutralizes acid rain and soil acidity through its alkaline ingredients, increases the productivity of marine plankton and plants by providing nutrition such as calcium and iron, prevents the occurrence of photochemical smog, and strengthens the microorganisms in soil to absorb inorganic salts. In addition, Krupnick and Portney (2001) argue that the benefits in investments to reduce the negative effects from yellow dust exceed its cost.

This paper focuses on estimating socio-economic cost from yellow dust in South Korea. The socio-economic cost in Beijing, China has been analyzed, using the technique of input-out analysis (e.g. Ai and Polenske, 2005). The socio-economic cost from yellow dust may be estimated in a wide range of areas in society.

1. Data Collection and Estimation Method

Recent research to estimate the socio-economic cost from yellow dust in South Korea includes work carried out by Hong (2004), Kang et al. (2004), and Shin (2005). These researchers have completed nation wide estimates, but they use different reference year and estimation methods, and vary in the socio-economic area included in the estimation. The differences are summarized as Table 2.

Table 2. Estimation of Socio-Economic Cost from Yellow Dust Damage in South Korea

Scholar	Year of Data Collection	Methods Used	Type of consequence
Hong	2002	BTM	all socio-economic areas
Kang et al.	2002 and 2004	CVM	decrease in amenity increase in disease product purchase for preventing the damage from yellow dust others (washing car, cloth, etc)
		BUA	early death resulting diseases aviation transportation
		BTM	all socio-economic areas
Shin	2004	CVM	decrease in amenity increase in diseases product purchase for preventing the damage from yellow dust others (washing car, cloth, etc)

Note: BTM; Benefit Transfer Method, CAM; Contingent Valuation Method,
BUA; Bottom-Up Approach

As is shown in Table 2, Kang et al.'s research is more comprehensive than the other two in terms of the socio-economic areas being analyzed and analytic method being used. Shin's research uses the most recent data. Hong estimated first the socio-economic cost per kilogram of yellow dust from Taiwan. Then, he estimated the socio-economic cost in South Korea, using a benefit transfer method. Kang et al. used three estimation methods. As part of their contingent valuation method, they conducted a survey with 1,000 samples of people aged 20-59 selected through purposive quota sampling on a national base in the year of 2004. Their questionnaire included 35 items related to yellow dust, such as awareness of the damage, perception on its seriousness, experiences with yellow dust damage in the past five years, the real damages the samples had in the past five years, and willingness-to-pay (WTP) for restoring ecosystem damages from yellow dust. As part of their bottom-up approach, they estimated the actual expenses in relation to the damage from yellow dust in the areas like medical treatment, industry, transportation, and product purchase for preventing the damage from yellow dust. They estimate total costs, adding expenses in each area. As part of their benefit transfer method, they used costs per kilogram of yellow dust estimated by the EC (1999) and Markandya (1998), and then transferred the average to South Korea.

Shin used a contigent valuation method. Like Kang et al., he conducted a survey with a 1,000 samples of persons aged 20-59, selected through purposive quota sampling in the year of 2004. The questionnaire included similar questions as in the work of Kang et al. (2004).

2. Estimated Socio-Economic Cost

Socio-economic Cost Estimated by Contingent Valuation Method. Kang et al. (2004) estimated the socio-economic cost assuming that yellow dust occurs an average 14 days per year. They first estimated the socio-economic cost per person, and multiplied this for the whole population and total cost. As is shown in Table 3, the cost was estimated as US$29.51 per person a year. Multiplied by total number of people in Korea an estimated cost of US$ 44.123 million results. The total socio-economic cost is then estimated as US$ 5,921.639 million when a discount rate of 7.5% is applied.

Table 3. Socio-Economic Costs of Yellow Dust, Using Cost per Person Estimates

Unit of Estimation	Cost Estimated
Cost per Person a Year (US$)	29.51
Cost Based on Whole Population a Year (US$ million)	44.123
Total Cost a Year (US$ million)	5,921.639

The total cost per year was estimated by the socio-economic areas on the basis of their composition ratio which was calculated from the response on the willingness-to-pay in the sample survey. As is shown in Table 4, the willingness-to-pay was composed of 33.8% for decrease in amenity, 36.6% for increase in disease, 14.5% for purchasing product for preventing the damage from yellow dust, and 15.1% for others such as washing car and cloth.

Table 4. Break Down of Costs per Socio-Economic Area

Socio-economic area	Socio-Economic Cost (US$ million)
Decrease in amenity	2,001.514 (33.8%)
Increase in disease	2,167.320 (36.6%)
Purchase to preventing damages	858.638 (14.5%)
Others (washing car, cloth, etc)	894.168 (15.1%)
Total	5,921.639 (100.0%

Shin conducted the sample survey one year after Kang et al.'s fieldwork, using the same socio-economic areas. However, the cost estimated by socio-economic area was not significantly different.

Socio-Economic Cost Estimated by the Bottom-Up Approach. Kang et al. (2004) applied the bottom-up approach to estimate socio-economic costs from yellow dust in three areas: early death, cause of disease, and aviation.

1) The number of early deaths was measured by the number of death caused by yellow dust for a year in 2002 among cardiovascular and respirator patients, yielding a number of 164.81 persons. The number of early death was multiplied by the value of human life per person (US$ 498,150) in South Korea, a value that was calculated through willingness-to-pay estimate (Shin and Cho, 2003). The total socio-economic cost caused by early death was estimated as US$ 82.1 million.

2) There are three kinds of medical treatments of diseases caused by yellow dust. One is simply to take medicine not prescribed by doctors. Another one is day-by-day treatment in hospitals or by visiting doctors. The other is in hospital treatment. Kang et al. (2004) estimated the cost of the latter two treatments. The dates and number of day-by-day and hospitalized patients was collected per disease. Expenses for day-by-day patient medical treatments and medicine expenses per patient were collected per disease. For the hospitalized patient, total treatment expenses were collected by disease. In addition, doctor's time spent on the treatment of patients was calculated and estimated as a monetary expenses, using a US$9.318 per hour cost and an average time of 20.3 minutes consumed for treating a single patient (MLSKG, 2002). Based on these data, the total socio-economic cost has been estimated in Table 5.

Table 5. Socio-Economic Cost by Disease

Disease	Treatment (US$ million)	Time-Loss (US$ million)	Total (US$ million)
Ophthalmological	0.79	0.15	0.94
Cardiovascular	0.62	0.03	0.65
Otorhinolaryngological	15.54	3.28	18.82
Respiratory	14.89	2.27	17.16
Total	31.84	5.73	37.57

As is identified from Table 5, the socio-economic cost caused by diseases is US$ 37.57 million. 90% arises for the treatment of patients and 10% for time-loss. Otorhinolaryngological diseases contributed most to the costs, followed by respiratory diseases; both contributed 95% to the total cost. This means the two are remarkably more sensitive to yellow dust than the ophthalmological and cardiovascular disease.

3) Aviation: There are two airlines in South Korea. They carry passengers and commodities domestically and internationally. The costs for the aviation industry from yellow dust are as decrease in sales due to flight cancellations. The decrease in sales is carried by airline companies, airport companies, and maintenance companies. Kang et al. (2004) estimated these costs for 2002 when 102 flights were cancelled due to yellow.

Table 6. Socio-Economic Cost of Airline Transportation

Analytic Items	Airline Company	Airport Company	Airplane-Maintenance Company	Total (US$)
Cancellation of flight	102	102	102	
Items included in analysis	Loss of sales vaolums from passenger Loss of sales volumes from commodity Cost by cacellation of passenger and commodity	Loss from landing charge Loss from lighting Loss from airport-use tax Loss from car parking	Loss of sales volume from passenger Los of sales volume from commodity	
Total cost Estimated	497,616	48,380	31,975	577,971

Note: Total Cost Estimated is the socio-economic cost estimated from the cancellation of flight on the basis of the items included in analysis

As is shown in Table 6, the cancellation of 102 flights caused a total cost of US$577,971. Airline companies suffered 86.0% of these costs followed by airport companies and maintenance companies.

Socio-Economic Cost Estimated by Benefit Transfer Method. The socio-economic costs estimated through the benefit transfer method (BTM) have been done by Hong and Kang et al. in South Korea (Table 2). The BTM requires existing research result applicable to a new research site. Hong used the cost estimated by Markandya (1998) while Kang et al. used the cost estimated by both Markandya (1998) and EC (1999). EC (1999) and Markandya (1998) estimated the average cost from particulate matter per kilogram as US$ 15.150 and US$ 27.982 respectively. Thus, the cost estimated through BTM does not allow an identification of costs for separate socio-economic areas. Therefore, Hong and Kang et al.'s estimation only total socio-economic costs. They multiply the quantity of yellow dust deposited in South Korea by the average cost per kilogram. Hong estimated this cost per month, while Kang et al. estimated it by particle size. Tables 7 shows Kang et al.'s estimation, which includes Hong's estimation.

Table 7. **Cost by Particle Size When EC and Markandya's Estimations Are Transferred**

Particle Size(μg)	Average Cost (US$ one million)	
	Transfer from EC	Transfer from Markandya
0.20 - 0.50	0.87	1.6
0.51 - 0.82	1.17	2.13
0.83 - 1.35	3.26	6.02
1.36 - 2.23	21.49	39.70
2.24 - 3.67	285.68	527.65
3.68 - 6.06	1,242.30	2,294.52
6.07 - 10.00	2,398.20	4,429.55
Total	3,952.97	7,301.19

Table 7 shows that cost estimates differ according to what existing data are used, suggesting that BTM is a less reliable method to estimate these costs, compared to contingent valuation or the bottom-up approach. However, BTM estimates more holistic socio-economic cost than contingent valuation method and bottom-up approach because these two methods are confined to particular socio-economic areas selected by the researchers. Regardless of which data are used in the BTM methods, the particle size of yellow dust between 3.68μg to 10.00μg occupies 92% of the total socio-economic costs. Meanwhile, the particle size less than 1.35μg causes very low socio-economic costs.

Ⅴ. Concluding Remarks

Yellow dust may reach every corner of South Korea and affect almost all socio-economic areas. The South Korean Government runs 22 observation sites for measuring it throughout the whole country. The frequencies of yellow dust occurrence during the past ten years show a trend of increase in terms of the days of yellow dust and the maximum density. The increase is significantly related to the high atmospheric pressure in Siberia and the temperature in Northern hemisphere.

Research techniques have been developed to estimate the socio-economic cost from yellow dust damage. They include input-output analysis, integration of environmental-economic evaluation technique, contingent valuation method, bottom-up approach, and benefit transfer method. Each technique has strong and weak points.

Three South Korean scholars have estimated the socio-economic cost from yellow dust, using these techniques. As is shown in Table 8,the total soci-economic cost from yellow dust damage in South Korea in the year of 2002 is estimated as US$ 3,900 million at minimum and US$ 7,300 million at maximum. The average of the two, US$5,600 million, is equivalent to 0.8% of GDP and US$ 117.00 per South Korean inhabitant.

The benefit transfer method results in the highest socio-economic cost, followed by the contingent valuation method and the bottom-up approach. However, there is a possibility for both contingent valuation method and the bottom-up approach to underestimate because the two do not cover all socio-economic areas. Meanwhile, the benefit transfer method has a possibility to underestimate and overestimate as well in that the technique relies on the average cost obtained from other research sites. From such a methological point of view, it is difficult to conclude which technique can estimate more accurately the socio-economic costs from yellow dust.

More reliable estimates may be done if the following is considered. (1) Common disaster-assessment techniques may not be applicable to evaluate the socio-economic impacts of yellow dust unless full data is available. However, analysts can gather data only from limited published information or field surveys. The lack of data is the most serious limitation to accurately estimate socio-economic costs from yellow dust. Thus, it is very important that the Government or private organizations collect better data on more areas, including loss of teaching in schools that are interrupted by yellow dust.

Table 8. Summary of the Estimates of Socio-Economic Cost from Yellow Dust in South Korea

Analytic technique	Socio-Economic Area	Socio-Economic Cost Estimated (US$ million)	Remark
Contingent valuation method	Decrease in amenity	2,001.514	
	Increase in disease	2,167.320	
	Product purchase for preventing damages from yellow dust	858.638	
	Others (washing car, cloth, etc)	894.168	
	Sub-total	5,921.639	
Bottom-up approach	Early death	82.100	
	Ophthalmological disease	0.940	
	Cardiovascular disease	0.650	
	Otorhinolaryngological disease	18.820	
	Respiratory	17.160	
	Aviation industry	0.578	
	Sub-total	120.688	
Benefit transfer method	The whole area	3,952.97	Transfer from EC
	The whole area	7,301.190	Transfer from Markandya

In addition, a time-series estimation of this data is necessary rather than ad hoc estimation in a given year. This is because the density and the continuous days of yellow dust vary between years. And finally, as described in the section of introduction, yellow dust has some positive impacts on nature such as reduction of global warming, prevention of red tide, neutralization acid rain and soil acidity, increase in the productivity of marine plankton and plants, etc. The benefits of these positive impacts may also be estimated using the existing techniques explained in this paper. If this is done, a more balanced estimate of socio-economic cost from yellow dust damage will be possible.

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