Assessment of the Economic Benefits of Water and Soil Conservation Engineering in North China

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Abstract: The assessment index system of the economic benefits of water and soil conservation engineering is studied in this paper. The assessing methods of the direct and indirect benefits of water and soil conservation engineering, and the sensitive analysis method are also researched too. Two special points in the theoretical research are: (1) It is clearly pointed out that internal return rate (*IRR*) does not stand for the return rate of the investment of a project, and can't be used as an assessment index to judge a project's economic effect, but can be used as a sensitive index. A new assessment index is given out to assess the investment return rate of a project. It is external return rate (*ERR*). (2) A reasonable assessment method is presented to estimate a conservation project's indirect economic benefits on alleviating rain erosion according to the decreasing quantity of erosion soil. We also made the economic assessment and sensitive analysis of the important water and soil conservation projects finished in last few years in North China by using the above methods, and presented some reasonable suggests about the future conservancy work.
Keywords: water and soil conservation, economic assessment, sensitive analysis, investment return rate

1 Intruduction

China has done a lot of work on water and soil conversance, especially the investment more and more in the last decade. The assessment of the economic benefits of water and soil conservation engineering is very important and urgent for analyzing the investment necessity and its effects, for planning and choosing higher efficient projects, for reducing social and economic cost. There are many studies in this field[1,2] but there is no well-rounded methods and experiences. The water and soil conversance project in Yongding River Valley in North China presents good actual experience and many data. We take the project as a example to research the index system of conversance effects, economic assessment index system, calculation methods of direct and indirect economic benefits for giving valuable references for other water and soil projects.

2 Economic assessment index system of water and soil conversancy

2.1 Index systems of conversancy effects and economic assessment

The index system of conversance effects is listed in Table 1. The contents of the economic assessment of water and soil conversance projects include the choice of economic assessment index system, the calculation of the indexes and sensitivity analysis. The major economic assessment indexes are net present value (NPV), benefit and cost ratio (BCR) and return ratio of investment (RRI), standing for the efficiency of capital).

NPV is the total increased net value or profit of a project in entire calculation period. BCR is the ratio of benefits and costs of a project in entire calculation period. That is the grow benefit of unit input. RRI is the annual return ratio produced by a unit input. Generally in theory and project fields, internal return ratio (*IRR*) is used to stand for. RRI. However, it is proved by many engineering practices that IRR does not really stand for the investment return ratio. It may be largely higher or lower than the real investment return ratio. There may be no or one or several *IRR*s for a project. Actually one project must has only one investment return ratio for an economic environment, or it must be wrong. It is proved by

our theoretical research that *IRR* is totally not investment return ratio but is only the critical point between a profit area and a loss area of discount rate. Therefor, external return ratio (ERR) should be used to stand BCR or investment return ratio. we will give special explain to ERR and *IRR* later.

Table 1 Index System of Conversance Effects of Water and Soil Conversance projects

No.	index	sub-index
1	input index	investment：CI, LI, PI
		input labor amount by local farmers
		engineering work amount
2	engineering index	area of comprehensive improvement
		area of farmland construction
		area of forest construction
		main works
3	effect index	increased area of comprehensive improvement
		decreased area of soil-erosion
		reduced quantity of soil-erosion
		reduced days of gale
		effects on flood control
		effects on water resources protection
4	direct economic benefits	increased total production value
		including increased value in agriculture, forest, stock-raising, industry and others
5	indirect economic benefits	benefits of reduced soil-erosion
		benefits of the improvement of weather and air
		benefits of water resources protection
		benefits of flood control
6	social benefits benefits	population of alleviated poor
		net income per capita

Notice: CI, LI, PI respectively stand for the investment from the central government, local governments, local people

2.2 Sensitivity analysis

The major purposes of sensitivity analysis are to know the elements that have important influence on the economic benefits of a soil and water conservancy project and how much of the influence in case these elements change. Sensitivity analysis should be done in three aspects:

(1) Influence of the change of economic environment

The change of economic environment is mainly reflected by discount rate. Discount rate will be higher if economic environment in a country or in the world is good, otherwise discount rate will is lower. The change of discount rate will influence the *NPV* of a project. The new *NPV*' corresponding to a new discount rate i_0' s also larger than zero, if a project' *NPV* is larger than zero for a given discount rate i_0 and if the new given discount rate i_0' is in the same discount area with i_0 set off by *IRR*. The new NPV' will be negative, if i_0' is not in the same discount area with i0 but in a neighbor area.

Examples:

① if i_0=0.06, *NPV*>0, only one *IRR* and *IRR*=0.2

NPV' >0, if i_0' <0.2

NPV' <0, if i_0' >0.2

② if i_0=0.06, *NPV*>0, two *IRR*s and IRR_1=0.02, IRR_1=0.3

NPV' >0, if 0.02<i_0' <0.3

NPV' <0, if i_0' <0.02 or i_0' >0.3

③ if i_0=0.06, *NPV*>0, without *IRR*

NPV' >0, for any i_0'

The only use of *IRR* is to cut out discount rate areas and make people know a project is profit or not profit for different discount rates. Therefor, *IRR* can be used as a sensitivity index about discount rate changes. It is totally wrong that *IRR* is generally used as a benefit assessment index of a project.

(2) Influence of the change of input

Both of investment and operation cost may change for a planning project. Operation cost may change for a constructed project, but its investment can't change. China is a developing country. The labor cost has larger raising space but the values of farmer products have not large raising space.

(3) Influence of the change of output

The direct economic benefits of most water and soil conservancy projects in China are mainly farm products. The values of farm products are continuously decreasing in recent few years. And in the near future the values of farm products will not raise highly, because China has jointed in WTO, market becomes better and better and technique becomes higher and higher. The indirect economic benefits values of water and soil conservancy projects on reducing soil-erosion, improving weather and air, protecting conservancy water resources etc. will increase as the national economic power become stranger and stranger and people's environment value become higher and higher.

3 Economic assessment methods

The economic benefits and costs of water and soil conservancy projects are listed in Table 1. The direct economic benefits are mainly the increased farm products. Most of the important areas of water and soil conservancy in China are relatively poor area where market has not well developed and most of farm products are used by farmers self. Therefore, most investigated data are increased quantity of products but not economic values. It is needed that to calculate the increased products into economic values by using general prices. Water and soil conservancy projects provided better production conditions. This is very important for the production increasing. And technique improvement and input increase are important too. Therefore, the increased values have to be properly shared. The calculation is more difficult, because all most all projects have not enough necessary data. We proposed a method to estimate the indirect benefit of a water and soil conservancy project on reducing soil-erosion. The method is a equivalent effect replacing method. Erosion soil produces many damages. For example, it deposits in a river bed and baffles floods moving, embarrasses navigation, and blocks water supply etc. It deposits in a reservoir and will decrease the usable capacity, shortens the using years and blocks water supply of the reservoir. Many measures are used to reduce these damages, such as sands rushing measures, sands clearing measures, banks, store sands with reservoir capacity etc. Actually, a vast amount of sands deposit in reservoirs in all most all rivers. Therefor, the cost to build per cubic meter of reservoir capacity is used to estimate the economic values of reducing soil-erosion in this paper.

There are the formulas of NPV and BCR in related reference [3]. Now the formulas of *IRR* and *ERR* are put out here for the needs of analysis.

the formula of *IRR*:

$$\sum_{t=0}^{n} (CF_t' - CF_t)(1 + IRR)^{-t} = 0 \qquad (1)$$

Formula can be changed into Formula (2).

$$\sum_{t=0}^{n} CF_t (1 + IRR)^{n-t} = \sum_{t=0}^{n} CF_t'(1 + IRR)^{n-t} \qquad (2)$$

the formula of *IRR*:

$$\sum_{t=0}^{n} CF_t (1 + ERR)^{n-t} = \sum_{t=0}^{n} CF_t'(1 + i_0)^{n-t} \qquad (3)$$

here $t = 0,1,\ldots,n$ are years. n is the last year of calculation period.

CF_t is negative cash in the net cash flow of year t (using absolute).

CF_t' is plus cash in the net cash flow of year t.

i_0 is the given discount rate, reflects the economic environment.

IRR、*ERR* are separatelly inturnal return ratio and external returnratio of the project.

Several pionts should be noticed: The first, one must be zero if the other is not zero for CF_t' 和 CF_t'' The second, i_0 stands for the opportunity costod capital. That is the return ratio of the capital if spent on other uses but not on this project. Its value should use the recommended value by related economic criterions or be carefully determined. The third, the differences of formula （2）and (3) are on the right sides. The right of formula (2) is the total terminal value of net benefits calculated by using *IRR*. It has no real economic meaning. Whowever, the right of formula (3) is real the total terminal value of net benefits calculated by using i_0 and has, therefore, real real economic meaning. So that, *ERR* is the investment return rate of the project but *IRR* is not. The fourth, formula (2) perhaps has no, one or several solutions. Formula (3) perhaps has one or solutions.

4 Economic assessment of the water and soil conservancy project in north china

4.1 Conditions of water and soil conservancy

Yongding River is one of the eight key areas of water and soil conservancy in China. We take the water and soil conservancy project finished in 1993—1997 as an economic assessment example. Yongding River is in North China. It spans Beijing City, Tianjin City, Hebei Province, Shanxi Province and Inner Mongolia Autonomy. The key area of water and soil conservancy is mainly on the upper area of this river. The upper area, totally 45,585 km^2， includes Yang River, Sanggan River and Gui River. Soil-erosion problem is severe here. The social and economic conditions of this area are listed in Table 2.

Table 2 Social and economic conditions of the water and soil conservancy area

indexes	units	compare		changes
		1992	1997	
land area	(km^2)	7,990	7,990	0
erosion loss area	(km^2)	4,929	2,253	–2,675
annual soil-erosion	(million t)	21.4	7.5	–13.8
rural population	（person）	893,815	905,264	11,449
labor forces	（person）	395,291	384,127	–11,164
cultivated area	(kha^2）	235	219	–15
total produced value	(million yuan)	1,632	3,785	2,153
poverty population	（person）	246,086	40,701	–205,385
net income per capita	(yuan)	569	1,613	1,044
food production	(kg/ha^2）	1,860	2,640	795
total food production	(million kg)	433	578	145
food per capita	(kg）	485	639	154

4.2 Economic assessment of the basic alternative

The basic alternative is the fished alternative from 1993 through 1997. The improvement effects of the basic alternative of the water and soil conservancy project are listed in Table 3. The input and output are in Table 4. The total direct benefit consists of the benefits of agriculture, forest, stock raising, industry and others. It is calculated by using the increased values from 1992 to 1997 and is properly shared with other important elements. The indirect benefit is only the benefit of reducing soil-erosion without

calculation other indirect benefits because of necessary data shortage. In order to calculate the benefit of reducing soil-erosion, we calculated the average cost per cubic meter usable reservoir capacity with the data of the reservoir projects built in last few years in China. The benefit of reducing soil-erosion of this project is about 3.1% of the total benefit. According to the economic environment in China, we take i_0=0.06. According to the assessment results of the basic alternative (see Table 5), *NPV* is 1537 million yuan. *BCR* and *ERR* are separately 1.3 and 0.1. The alternative has one *IRR* (0.716). The difference between *IRR* and i_0 is 0.656. Therefore, the profit discount area is quite large. All these show that the basic alternative is profitable and feasible in economy.

Table 3 Improvement effects of the basic alternative

improvement area (km^2)	reduced area of soil-erosion (km^2)	annual reduced soil-erosion (million t)	reduced ratio (%)	annual reduced days of gales (day)	reduced ratio (%)
3,663	2,675	13.82	66	16	41.4

Table 4 Input and output of the basic alternative (million yuan)

total investment	annual project maintenance	annual production cost	total annual operation cost	annual direct benefit	annual indirect benefit	total annual benefit
342.24	0.17	651.84	652.01	869.11	28.02	897.13

4.3 Sensitivity analysis

We take 9 alternatives to make sensitivity analysis (Table 5). The former 7 alternatives may take place for the analysis project, but the last two can't take place for the project. It is because that the construction of the project finished in 1997. However, the last two may take place for the future projects of water and soil conservancy in this valley and other valleys, and have reference meaning for them. The changes of important elements in each alternative are in Table 5. Other elements not listed in the table in sensitivity analysis alternatives are the same with the basic alternative. The sensitivity analysis results show that: (1) This water and soil conservancy project is profitable, feasible and safe in economy even though the operation cost increases 20% and benefit decreases 20%. (2) Real changes of discount rate can only change the profit values of this project but can't change the profit property because the profit discount rate areas in all alternatives are quite large.

Table 5 Sensitivity analysis results

	alternatives	*NPV* (million yuan)	*BCR*	*ERR*	*IRR*
0	basic alternative	1,537	1.295	0.100,28	0.715,92
1	operation cost+10%	1,157	1.207	0.089,97	0.661,84
2	operation cost +20%	777	1.130	0.079,89	0.593,96
3	operation cost –10%	1,917	1.398	0.110,83	0.761,44
4	operation cost +10%	2,060	1.396	0.111,64	0.776,95
5	benefit in operation +20%	2,583	1.497	0.122,13	0.827,94
6	benefit in operation –20%	491	1.094	0.074,21	0.526,32
7	operation cost+20% and benefit in operation+10%	1,300	1.218	0.091,84	0.683,44
8	investment and operation cost +20%	497	1.080	0.072,07	0.263,91
9	labor price in construction +100%	1,341	1.248	0.093,61	0.431,08

5 Conclusions

We can get the following conclusions from the results of theory researches and real calculations of the water and soil conservancy project in north China:

(1) *IRR* does not be the investment return ratio and can't be used as an economic assessment index of a project. *ERR* is the investment return ratio and really stands for the using efficiency of a project and should be used as an economic assessment index of the project.

(2) The project of water and soil conservancy in Yongding River Valley finished from 1993 through 1997 is profitable and feasible in economy. It has strong power to resist economic risk.

(3) Generally, local farmers input a lot of labors into water and soil conservancy projects. For example, the calculated investment of the local farmers labors put into the research project takes 64% of the total investment of this project. The key areas of water and soil conservancy in China are generally relatively poverty at present. The labor prices are very low. Therefore, water and soil conservancy projects' construction costs are relatively low. The economic properties are generally good. The labor prices will have large raising space in the future. This will influence the economy of water and soil projects. It should be pay more attention to the labor prices, works and improvement effects to choose the best combination in the planning and design of water and soil conservancy projects.

(4) The raising spaces of the direct benefit of water and soil conservancy projects are relatively small, but the raising spaces of indirect benefits in reducing soil-erosion, improving weather and air, protecting water resources etc. are larger. The benefits both direct and indirect benefits are almost all realized in social benefit form. Therefore, the investments of water and soil conservancy must mainly rely on the government investment.

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