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Article

Is the "Ecological and Economic Approach for the Restoration of Collapsed Gullies" in Southern China Really Economic?

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Abstract: Collapsed gully erosion constantly plagues the sustainability of rural areas in China. To control collapsed gully erosion, an ecological and economic approach, which uses tree plantation to gain economic benefits and control soil erosion, has been widely applied by local governments in Southern China. However, little is known about the economic feasibility of this new method. The objective of this study was to determine the effectiveness and economic benefits of the new method. Based on a case study in Changting County, Southeast China, two farms were selected to represent a timber tree plantation and a fruit tree plantation, respectively. The Annual Capital Capitalization Method and Return on Investment (ROI) were selected to conduct cost-benefit analysis. In contrast to previous studies, we found that the new approach was far from economic. The value of the newly-built forestland in Sanzhou Village and Tufang Village is 2738 RMB ha^{-1} and 5477 RMB ha^{-1}, respectively, which are extremely lower than the costs of ecological restoration. Meanwhile, the annual ROI is −3.60% and −8.90%, respectively, which is negative and also far poorer than the average value of forestry in China. The costs of conservation were substantially over the related economic benefits, and the investors would suffer from greater loss if they invested more in the conservation. Low-cost terraces with timber trees had less economic loss compared with the costly terraces with fruit tree plantation. Moreover, the cost efficiency of the new approaches in soil conservation was also greatly poorer than the conventional method. The costs of conserving one ton soil per year for conventional method, new method for planting timber trees, and planting fruit trees were 164 RMB, 696 RMB, and 11,664 RMB, respectively. Therefore, the new collapsed gully erosion control methods are uneconomic and unsuitable to be widely carried out in China in the near future.

Keywords: economic feasibility; cost-benefit analysis; collapsed gully erosion; environmental conservation

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1. Introduction

Collapsed gully erosion refers to a kind of soil erosion that eroded hills collapse and pit under the pressure of water and gravity [1]. It is the advanced stage of upland gully erosion. Collapsed gully erosion mainly occurred in tropical regions, such as tropical Asia, Mediterranean regions, and African highlands [2–4]. Southeast China has suffered from serious collapsed gully erosion. Recently, a large-scale survey on collapsed gully erosion was widely conducted in granitic red clay soil areas of southern China [5]. The survey showed that there were 2.39×10^5 collapsed gullies, which covered 1.22×10^5 ha in seven provinces of Southern China. The total area affected by the erosion in Southern China was 4.83×10^7 ha, with a population of 0.16 billion, which accounted for 5.04% and 12.40% of the total area and population of China, respectively [1]. As a type of serious soil erosion, collapsed gully erosion has caused multiple natural disasters, such as frequent floods, debris flows, landslides, and soil loss. The survey showed that 3.8×10^5 ha of cropland, 5.54×10^5 houses, 37,000 km of roads, 11,000 bridges, 9000 reservoirs, and 73,000 ponds were destroyed by collapsed gully erosion in Southern China from 1949 to 2005, and the direct economic damage from cropland loss alone was 0.55 billion RMB [1,6]. Therefore, it is necessary to take effective measures to prevent and control collapsed gully erosion in order to improve the livelihood of people in these regions.

A lot of approaches have been put forward to stabilize, rehabilitate, or restore collapsed gully erosion. These approaches can be divided into two types according to their emerging periods and characteristics: conventional approaches and new approaches. Generally, conventional treatments include protecting the headcuts from further erosion, diverting overland flows away from steep slopes, constructing check dams to capture sediment, and planting grass sod and trees to stabilize gullies [7–11]. Suitable species with maximum ecological effect are often selected in the re-vegetation for rehabilitation because various plant species have different potentials to control collapsed gully erosion [12,13]. These conventional approaches have been widely utilized in China for several decades due to the obvious effect, low costs, and low technological requirements [8]. However, the conventional approaches only emphasized the ecological significance of erosion control, and neglected the livelihood of local residents [5]. Consequently, though many traditional measures have been proved to be effective, they are rarely adopted by farmers in the long term and are not applied at large scales due to the lack of rapid economic benefits [2,14].

Given the disadvantages of the traditional method, a new approach, which claims to integrate ecological engineering measures with local economic development, has been put forward and conducted in recent decades in Southern China [5,7,15]. The new approach mainly includes land reshaping and terracing, which smoothes land surface to less than 25 degree and constructs terraces for planting economic forests, and re-plantation with grass and economic trees, which stabilizes and controls gully erosion [5]. Compared with the traditional method, the greatest advantage of the new approach is to control collapsed gully erosion through agricultural development, which could provide a win-win situation in terms of ecological restoration and livelihood improvement [5,6]. The new approach has been identified as "An Ecological and Economic Approach for the Restoration of Collapsed Gullies", which has also been considered by the Ministry of Water Resources of China as a typical method to popularize in Southern China [5,6,15]. Though the ecological and economic approach has been widely reported in China, little is known about the economic feasibility of the new method. Moreover, literature focused on the new treatment often overstated the economic benefits by utilizing problematic calculation methods, which need to be reevaluated and corrected to better assess the feasibility of this approach in erosion control [5,6,15–17]. The objective of this study is to fill this gap by scientifically evaluating the economic benefits of the new approach, and to determine whether the new approach is economic or not, based on the survey in Changting County, Fujian Province of Southeast China. In other words, the aim of the study is to answer the question: Is the "ecological and economic approach for the restoration of collapsed gullies" in Southern China really economic?

2. Methods

2.1. Study Area

Changting County is located in the Western Fujian Province of Southeast China (Figure 1), covering a total area of 309,959 ha, with a population of 508,900 in 2010. Owing to being situated on the southern part of WuYi Mountain, the topography of Changting is characterized by hills and uplands, which jointly account for 97.3% of the total area. As for land-use types, according to the published data of the Land and Resources Bureau of Changting County, cropland, orchard and forestland, grassland and other farmland, construction land, and other land accounted for 9.48%, 82.54%, 2.67%, 2.08%, and 3.23%, respectively, in 2005. It is also characterized by a humid, subtropical monsoon climate with high mean precipitation (1730 mm yr^{-1}) and warm annual temperatures (a mean of 18.3 °C), and it is primarily covered by loose granite red soils [18]. Historically, it was covered by abundant vegetation and had little soil erosion. However, human activities have increased the intensity and scale of gully erosion, leading to serious collapsed gully erosion in the past half century [5,18]. Changing County has gradually become a typical region of collapsed gully erosion with large areas, serious erosion intensities, and severe damage to local livelihood in China [19,20].

As one of the most typical areas of collapsed gullies in Southern China, Changting County has 3583 collapsed gullies with an area of 6304 ha. According to statistical data of the Water and Soil Conservation Bureau of Changting County, local governments endeavored to treat 761 collapsed gullies, including 160 collapsed gullies with the ecological economic approach, from 2000 to 2009. Among these treated collapsed gullies, the gully erosion control in Sanguan'ao of Sanzhou village and Young Century Forest of Tufang village became demonstration projects by virtue of their better effectiveness in controlling soil erosion, long history of treatment, and higher cost effectiveness. They represented the approach of planting timber trees and fruit trees, respectively, and became the study models of Changting County and even of the red soil areas of Southern China. The success of the new approach with respect to ecological and economic aspects has been widely reported, and the new treatment pattern has been funded and considered by the Ministry of Science and Technology of China and the Ministry of Water Resources of China as the prime example of collapsed gully control [5].

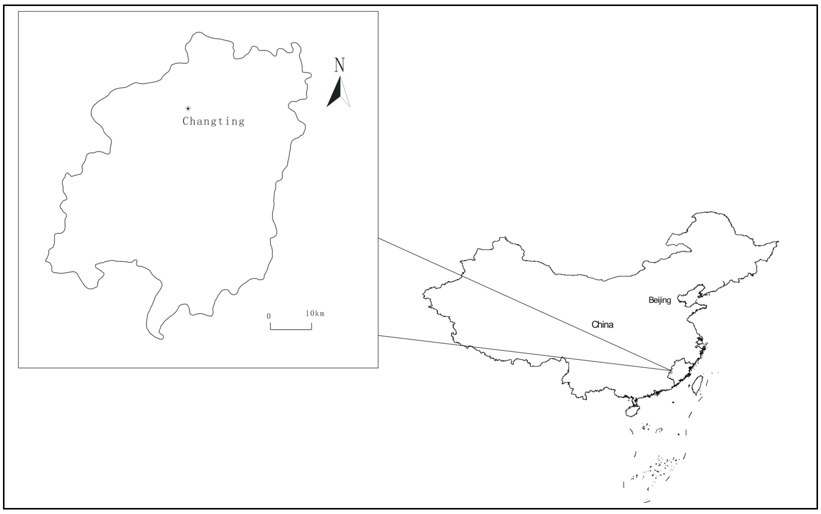

Figure 1. Location of Changting County.

2.2. Data Collection

The main data for the present study were collected from 10 July to 25 July, in 2013, through a questionnaire survey conducted by the authors. Multiple stratified sampling procedures were used for selecting respondents. In the first stage, two new approaches for controlling gully erosion (planting timber trees and planting fruit trees) were selected to represent different methods. In the second stage, the treated collapsed gullies, with clear input and output, were chosen as the sampling gullies. Because the new approach is a bioengineering method, which includes many specific measures and needs several years' of remarkable inputs to consolidate the gully, the cost composition was very complex. If the treatment was organized by the private investment, only educated and calculating farmers would be able to record the detailed inputs. Hence, one treated collapsed gully in Sanguan'ao of Sanzhou village, invested in by an affluent household, with clear input data was selected as one sample. The gully was transformed into a timber forest farm. Except for this gully, the other treated gullies were almost exclusively sponsored by the local government over the past five years. For the government-invested gully erosion treatment, the financial budgets of projects have been formulated according to the yearly total collapsed gully treatment, other than separate accounting for every gully. Thus, it is difficult to acquire the costs for one single gully treatment project. More importantly, collapsed gullies, restored with the same approach, have similar cost-benefit relationships. Thus, the demonstration case in Young Century Forest of Tufang village with clear inputs was selected as the other case for this study. In a word, two collapsed gullies, restored using the new approaches, which have been regarded as demonstration projects and have independent financial budgets, are selected as cases for this study (Table 1). These two cases, with specific costs and benefits, could also be considered to be most representative for gully erosion control in Changting County.

Table 1. Costs and benefit collapsed gully treatment adopting the new approach in Changting County.

Site	Costs (RMB)	Increased terrace (ha)	Costs of terrace (RMB ha^{-1})	Economic trees	Town	Investor	Treating year
Sanguan'ao in Sanzhou village	63,543	3	21,181	*Cunninghamia lanceolata*	Sanzhou	Individual	2000
Young Century Forest in Tufang village	652,500	2	326,250	*Myrica rubra*	Hetian	Government	2012

Note: Data in value terms are calculated at the comparable prices of 2012; 1 USD = 6.3125 RMB in 2012, the same below. *Source*: Our survey in 2013.

After choosing the sampling treated gullies, we conducted interviews with related investors and forestland managers with a questionnaire to gain the costs and benefits of gully treatment. The questionnaire includes 18 questions, primarily about the labor, material, and financial inputs in different measures (engineering measures, vegetative measures, and independent costs), species of planted trees, treating year, area of newly built terrace, annual forestland rent, evaluation of past investment, intention of future private/government investment on gully conservation, *etc*. As for the Sanzhou village case, we interviewed the householder on the costs and benefits of the ecological treatment, and his wife complemented some information. As for the Tufang village case, we mainly interviewed two leaders in the Water and Soil Conservation Bureau of Changting County who answered for the gully erosion control to gain the investment composition and area of the newly built terrace. Furthermore, we also interviewed the forestland tenant of Young Century Forest to get the potential bid price for renting the newly formed terrace. In addition, we also interviewed another 10 forestland managers close to the study cases regarding the land rent. The average value was used to represent the land rent of two sites. Finally, we acquired the cost structure of the two cases (Table 2).

Table 2. The cost structure of collapsed gully treatment in Changting County (Source: Our survey in 2013).

Cost type	Sanzhou village Site		Tufang village Site	
	Costs (RMB)	Percentage (%)	Costs (RMB)	Percentage (%)
Engineering measures	57,983	91.25	537,334	82.35
Vegetation measures	3495	5.5	25,252	3.87
Independent costs	2065	3.25	89,915	13.78
Subtotal	63,543	100	652,500	100

In one of the cases, collapsed gully was transformed into orchards (Figure 2), and in the other gully was converted to a timber tree farm (Figure 3). The second treatment started in 2000, and was low-cost due to low labor costs at that time, and a comparatively simple treatment for planting Chinese fir (*Cunninghamia lanceolata*). It was carried out and invested in by landowners, whose principal pursuit was profit maximization. Thus, the terrace created in this project is not as broad and standard as the first treatment in Tufang village, which is limited by funds and technology. The treatment in Tufang village was invested in by the local government, which focused on the demonstration purpose in soil conservation rather than economic benefits. In addition, the project was implemented by professional engineering companies. The conventional method usually includes three parts: blocking runoff by constructing concrete channels at the top, consolidating the gully cliff by vegetation at the middle, and building check dams to intercept sediment at the bottom [21]. The conventional approach did not change the steep slopes to permit afforestation and farming, therefore, cannot produce economic yields [5].

Figure 2. Photographs of collapsed gully treatment in Young Century Forest, Tufang village, Changting County: (**Top Left**) Original collapsed gullies. (**Top Right**) Bioengineering measures in the first year. (**Bottom**) Restoration conditions in the third year.

In addition, some secondhand data about collapsed gully treatment in Changting County were also collected from related administrative departments, such as the Water and Soil Conservation Bureau and the Bureau of Forestry of Changting County. Moreover, we interviewed eight key leaders answering for gully erosion control (four leaders in the Water and Soil Conservation Bureau of Changting, two leaders in the Water and Soil Conservation Station of Hetian Town, and two leaders in the Water and Soil Conservation Station of Sanzhou Town) to enhance our overall understanding of these projects, especially in order to acquire their personal judgments on the cost effectiveness of the gully erosion treatment and future planning on conservation. Qualitative information was used to indirectly testify our viewpoints. The number of interviewed leaders was also randomly selected, determined by their availability in the office during our survey. All prices were converted to comparable prices of 2012 to remove the effect of inflation.

Figure 3. Photographs of collapsed gully treatment in Sanguan'ao, Sanzhou village, Changting County: (**Top Left**) Original collapsed gullies. (**Top Right**) Bioengineering measures in the first year. (**Bottom**) Restoration conditions in the thirteenth year.

In order to assess the effects of the different methods in soil conservation, we established 24 paired plots (20 m × 20 m) with collapsed gullies [5]. In each pair, one plot was treated, and the other was untreated to serve as a control. Then, the soil erosion at each site was monitored using the usual concrete sedimentation ponds from the Water and Soil Conservation Bureau of Changting County. After the measurement of the soil erosion, we conducted repeated-measures ANOVA to identify whether there were significant differences among four subgroups (untreated, treated by conventional methods, treated by planting timber trees, treated by planting fruit trees). If there were differences among the subgroups, LSD (Least-Significant Difference) was used to identify which specific combinations of values differed significantly. All tests could be accomplished by SPSS 12.0.

2.3. Economic Analysis Model

The benefits of soil and water conservation involve many aspects, which are often dependent, integrated, interrelated, and complex. It is impossible and unnecessary to conduct all-round on-site and off-site benefit evaluation. Thus, direct and principal benefits were usually used as the representatives of benefits in soil and water conservation [22]. In general, the primary benefits of conservation can be classified into two parts: economic benefits and ecological benefits. Furthermore, the impacts of soil erosion in economic losses, to a large extent, depended on the economic level and the seriousness of the soil erosion. Supposing the same intensity of soil erosion, the economic costs of soil erosion close to metropolises are frequently larger than those of remote and poor rural areas [23,24]. On the other hand, it is difficult to quantify the ecological benefits of conservation because of complex marginal effects, a complicated interrelationship of loss-inducing factors, and insufficient credible data [23,24]. Therefore, direct economic benefits and primary benefits of conservation were selected as the principal indices to measure the benefits of water and soil conservation. In addition, the key benefits of treatment would be different in different periods. In general, the ecological benefits (such as soil conservation) would be dominating in the short and medium terms. When the soil erosion of treated gullies was stable, the economic benefits could be primary benefits in the long term.

As far as the economic benefits are concerned, collapsed gully treatment could be considered as an investment. Its economic feasibility could be judged with some economic models. It should be noted that the research considers costs and benefits of the new approach, which incurs only at the on-site level. The off-site benefits of collapsed gully control are important from social perspectives, such as water supply and soil conservation, benefiting downstream inhabitants [25]. These off-site benefits belonged to ecological benefits, which will be calculated in what follows. Therefore, only costs and benefits at the on-site level, from the perspective of investors, were included in the cost-benefit analysis. The costs mainly contain the initial investment of bioengineering measures, exclusive to follow-up maintenance costs. Generally, the costs contain three parts: costs of biological measures (such as planting grass sod), costs of engineering measures (such as constructing waterways, terraces, check dams, debris dams, retaining walls, field roads, and consolidating the earth), and independent costs (such as construction management fees, costs of engineering superintendence, survey, and design expenses) (Table 2). The major benefits of the new gully erosion control considered in this study are the rent of newly formed terraces.

It was reported that, even after terrace building and forest recovery, gullies remain susceptible to reactivation if conditions change. Thus, the constructed terraces could result in new gully erosion due to insufficient follow-up checks and maintenance, and terraces could be destroyed by aggravated gully erosion [26,27]. The forestland managers are not willing to invest in follow-up maintenance due to poor returns and limitation of land tenure (general land contract period ranging from 30 to 50 years), and the local governments do not stress the maintenance, owing to one-sided achievement views of governmental officials and the limitation of project fund systems (conservation project periods mainly range from three to five years) in China.

Two models were selected to conduct cost-benefit analysis: The Annual Capital Capitalization Method (ACCM) and Return on Investment (ROI) [28]. Both models are popular methods in evaluating the economic feasibility of an investment, which are also easy to understand and supplement each other based on limited data. The former is a method to calculate the forestland value using the yearly stable benefits and the interest rate if the newly built forestland can endure infinitely. The forestland value should be calculated by summing the lifetime rent if the forestland has a certain lifetime. Then, the forestland value can be calculated using the method. The project is only viable if the calculated forestland value is higher than the costs of restoration. The latter is a method to calculate the profitability ratio that is utilized to evaluate the efficiency of an investment. The yearly returns on investment are usually used to take the time value into account. The investment is profitable only when the ROI is greater than the benchmark ROI of the same sector. We can use the Annual Capital

Capitalization Method to calculate the overall economic benefit of an investment, which could show the quantity of profit. Additionally, we can also use ROI to evaluate the profitability by the ratio. Both methods complement each other and obtain comprehensive results. Excel 2003 was used to perform the calculation of ACCM and ROI.

As far as the ecological benefits are concerned, the soil conservation could be considered as a primary benefit of collapsed gully treatment. Given practical impacts of soil erosion, erosion modulus reduction was selected as an indicator to represent the ecological benefits of conservation. Some research testified to the quantification of soil erosion values in terms of weight [23]. In order to evaluate the cost effectiveness of different conservation methods, we used cost efficiency to measure the cost of per unit soil erosion reduction in a period of one year [29]. The calculating process is as follows: first, using the total costs of new conservation methods in order to deduct the total rent of terrace duration (50 years) to get the net costs of treatment; second, the net costs per acreage, divided by soil erosion reduction in the period of one year, can be used to measure the cost efficiency of different conservation methods. For cost efficiency, a smaller value is better.

3. Results

3.1. Cost-Benefit Analysis of the "New Methods"

As introduced in the preceding text, ACCM and ROI were used to calculate the direct economic benefits of conservation. Before proceeding to the calculation of the economic benefits, we needed to ensure the duration of the newly built terrace before its destruction. The investors hardly attach importance to follow-up, facility maintenance in view of the decreasing contract period. Therefore, the newly built terrace would come to ruin, resulting from the combination of no maintenance and fragile natural conditions [26,27]. In addition, it is estimated that the lifetime of the terrace is 50 years. Supposing the annual land rent of newly formed terraces is constant, returns and ROI of each investment could be calculated (Table 3). The annual ROI is −3.60% and −8.90% in Sanzhou village and Tufang village, respectively, which is negative and far lower than 6%, the average ROI of forestry in China [30]. On the other hand, according to the official data of China, the five-year deposit rate in 2012 was 4.75% and the commercial loan interest rate for more than five years was 6.55%. Thus, 5% was selected as the interest rate to calculate the present value of forestland. Then, the value of the forestland (terrace) is 2738 RMB ha^{-1} and 5477 RMB ha^{-1} in Sanzhou village and Tufang village, respectively, which are extremely lower than the costs of ecological restoration. The net loss was 18,443 RMB ha^{-1} and 320,773 RMB ha^{-1} for the above two sites, respectively (Table 3). According to the above economic analysis, it is concluded that the ecological and economic approach is actually uneconomical. The investment in the gully control, using the new approach, is infeasible in terms of economy.

In addition, there was a great difference in the economic characteristics between the simple terrace pattern (planting Chinese fir) and the standard terrace pattern (planting myrica rubra) in Changting County. As shown in Table 3, though the simple terrace pattern in Sanzhou village was also not viable in terms of economy, its economic effect was better than that of the standard terrace treatment. The poor marginal benefit of the investment in collapsed gully control may account for the difference. Results of this study indicated that the ecological and economic approach (forming terrace) in

Changting County is uneconomical, and the loss may increase with increases in investment. It should be noted that the two cases were not implemented in the same year, which may affect the comparability. Indeed, the costs of conservation and land rent have increased substantially since the past decade. However, the growth in costs greatly surpassed that of benefits, which meant that it had insignificant impacts on the results of this study.

Table 3. Economic feasibility of gully erosion control using the new approach in Changting County (Source: Our survey in 2013).

Site	Costs of terrace (RMB ha^{-1})	Annual forestland rent (RMB ha^{-1} year^{-1})	Forestland value (RMB ha^{-1})	V-C (RMB ha^{-1})	ROI (%)
Sanzhou village	21,181	150	2738	−18,443	−3.60
Tufang village	326,250	300	5477	−320,773	−8.90

Note: Forestland rent is calculated according to 50-year lifetime of the terraces without follow-up maintenance; V means value of terrace for planting trees; C means costs of terrace.

3.2. Comparison between New and Conventional Methods

Because the conventional method of gully erosion control has involved the installation of diversion channels to direct runoff away from steep slopes, constructing dams to intercept sediment, planting grass to consolidate the gully grounds, it usually has no economic profits. However, the conventional method is useful in soil conservation. In order to analyze and compare the technical and cost advantages and disadvantages of the new approaches with the conventional ones in terms of ecological benefits, we used cost efficiency to ensure the prior methods. First, it is necessary to determine the indicator of ecological benefits. As above discussed, the key opportunity costs of gully erosion in the research area are forestland loss. Owing to the land loss is the principal costs of soil erosion in Changting County, the net costs per unit, divided by soil erosion reduction in the period of one year, can be used to measure the cost efficiency of different conservation methods. It should be noted that the soil erosion reduction is the yearly average value. Finally, we acquired the comparative results of conventional method and new methods for gully erosion control (Table 4).

Table 4. Cost efficiency of three conservation methods in Changting County (Source: Bureau of Water and Soil Conservation in Changting County; our survey in 2013).

Conservation methods	Net cost (RMB ha^{-2})	Erosion modulus reduction (ton ha^{-2} year^{-1})	Cost efficiency (RMB ton^{-1} year^{-1})
Timber trees	18,443	26.5	696
Fruit trees	320,773	27.5	11,664
Conventional method	3600	22	164

As seen in Table 4, the erosion modulus reduction for conventional method, new method of planting timber trees, and new method of planting fruit trees was 22 ton ha^{-2} year^{-1}, 26.5 ton ha^{-2} year^{-1}, and 27.5 ton ha^{-2} year^{-1}, respectively. These results showed that the effects of the conventional method and the new methods in soil conservation were similar. However, their net costs were remarkably different. The net costs of the conventional method, new method of planting timber trees, and new method of planting fruit trees were 3600 RMB ha^{-2}, 18443 RMB ha^{-2}, and 320773 RMB ha^{-2}, respectively. Correspondingly, the cost efficiency was extremely discrepant. The cost of the conventional method, new method of planting timber trees, and new method of planting fruit trees in reducing soil erosion were 164 RMB ton^{-1} $year^{-1}$, 696 RMB $ton^{-1}year^{-1}$, 11664 RMB ton^{-1} $year^{-1}$, respectively. Therefore, the conventional method is the most economic in terms of soil conservation, and the new methods are practically not cost effective in conservation. In a word, the cost efficiency of the new methods is remarkably poorer than the conventional method.

4. Discussion

Collapsed gully erosion is the most serious soil erosion, which imperils the rural sustainability of many developing countries [2,3,25]. Poverty resulted from soil erosion leads to further ecological degradation and, ultimately, forms a vicious circle known as the ‘‘poverty-environment trap’’ in these environmentally fragile regions [18,31]. Environmental goals cannot always be achieved in the long term without economic development, which supplies sustainable livelihoods to the participants of the projects [2,32,33]. Therefore, integrating soil and water conservation with sustainable livelihoods became the core of conservation projects. To meet these challenges, the integration of thought and experiment are right and should be encouraged for the long-term sustainability of social-ecological systems. However, economic feasibility is the crucial basis for these integrated projects. Therefore, it is essential to carry out cost-benefit analyses of the new approach using scientific methods before it is spread to large areas.

This study has addressed the economic impacts of restoring collapsed gullies into forestland (terrace) by estimating the forestland value and ROI of the projects. Our results showed that the ecological and economic approach is absolutely not economic. On the contrary, the investment in gully erosion control using the new approaches would lead to severe economic losses. The annual ROI for planting timber trees and fruit trees is −3.60% and −8.90%, respectively. In addition, the net economic losses were 18,443 RMB ha^{-1} and 320,773 RMB ha^{-1} for the above two sites, respectively. Furthermore, the cost efficiency of new methods in soil conservation was greatly poorer than the conventional method. These research results were completely opposite to previous studies, which generally claimed that great success both in ecological and economic aspects had been realized [5,15–17]. Some researchers even considered the collapsed gully erosion as an opportunity for rural sustainability other than a serious problem [5,17]. The crucial reason of the research disparity was that they used problematic calculation methods, which attributed all the net incomes of later economic forest management to bioengineering measures, but neglected the function of subsequent investment, labor, skills, and market. These previous studies also overlooked the costs of follow-up production investment and labor. Such a calculating method would be analogous to valuing timber at the price of fine furniture. In fact, the rent of the newly formed forestland (terrace) should be the ultimate output of the collapsed gully treatment if deducting the function of other economic factors. Of course, the scientific and accurate input-output analysis associated with forestry products, from the tree plantation or the cost benefit analysis of this approach over the lifespan of a project could also reach convincing results on the condition of better data accessibility. However, in fact, it is impossible for common farmers to provide accurate data during the lifespan of the project or tree rotation period. Thus, our simple method can overcome these shortcomings and provide an objective judgment.

On the other hand, previous research did not consider the costs of initial investment, which was also an important factor leading to incorrect conclusions. Many investigations ignored opportunity costs of conservation investment. These researchers would not have obtained exciting conclusions if they took into account the time costs of the initial investment (*i.e.*, setting the annual interest rate at 5%). In the less developed rural areas, funds are the scarcest capital with relatively high rates of returns [34]. If the funds were invested to sectors with larger multiplier effects (such as infrastructure, education, manufacturing with higher connectivity) rather than into uneconomic gully erosion treatment, the total social-economic benefits of the investment would be higher and the combined poverty alleviation and conservation could be realized sooner. Because *in situ* urbanization and industrialization are potential alternatives to tackle poverty and conservation, by shifting the rural poor households from the traditional natural resource utilization and providing higher-income off-farm employment, besides the integration strategy [35,36]. Any ecological benefits should be based on reasonable economic benefits, no matter the practical or potential benefits [25].

It was reported that about 8.9×10^5 RMB was invested to the collapsed gully treatment in Changting County from 2011 to 2013, and 10 billion RMB had been invested to control collapsed gully erosion since 2005 in China [5,6]. Too many social funds for environmental conservation means less funds allocated to other sectors. According to the theory of optimizing resource allocation, the capital should be allocated to these sectors, with higher returns and low risk in the free market. There is no doubt that environmental protection is a public service, but this does not mean that environmental investment should not consider cost efficiency. Therefore, it is irrational and unsustainable to attach excessive importance to ecological benefits but ignore the related economic benefits.

Therefore, it is necessary to reevaluate the utility of various approaches for collapsed gully treatment, according to the above analysis. Innovation in gully erosion control research is rather limited compared to innovation in gully erosion process research. Conventional gully control approaches were widely used in the world by virtue of effectiveness and cost efficiency [2,3,21,37,38]. Land smoothing or reshaping, which smoothes the surface to less than a 25 degree slope, and forms a terrace for forestry is used as a new method to control gully erosion in many countries [26]. However, it is restricted to deal with active complex gully systems and is not widely applied due to high conservation costs. Poor farmers cannot afford to invest in expensive gully control, and rich farmers are not willing to adopt them in the long run and at larger spatial scales because these measures could not produce acceptable profits [2]. Meanwhile, famers' dependence on agricultural land has gradually decreased and off-farm income has become the primary income source due to poor agricultural economic profits in the study area [18]. The price boom of forestland will not happen in the near future. It is not possible that the new approach would become economically viable in the near future in China, which is different from other poorer regions [39]. Therefore, low-cost vegetative practices and simple engineering measures of gully erosion control (such as planting grass and trees without geomorphological modifications) are more suitable and widely used in less developed regions than the expensive engineering measures (such as transforming gullies into terraces) [2,19,40]. The expensive approaches only become economically viable in few cases, where benefits exceed the conservation costs. One example is that active collapsed gullies may threaten the lives of downstream residents, and the relocation costs could be much higher than management practices.

5. Conclusions

Using cost-benefit analysis, this study assessed the economic feasibility of new methods for gully erosion control. The models of ACCM and ROI were used to evaluate the economic viability of new approaches over a 50-year period. Our results showed that the costs of the new approaches actually exceeded the benefit. The investment in conservation is uneconomic, and the more the investment, the more the economic loss. Moreover, cost efficiency was adopted to compare the cost-effectiveness of different conservation methods in soil conservation. The results also proved that the new approaches had poorer cost efficiency than the conventional method in soil conservation. In a word, the new approaches should not be given priority over the conventional method because they are uneconomic as an investment, and have poorer cost effectiveness in conservation.

These findings provide important implications for selecting applicable gully erosion control approaches in Southern China. Cost efficiency should be used as an important criterion for the selection of appropriate conservation methods. Given extremely spatial disparities in natural conditions and socio-economic backgrounds in China, a more comprehensive cost effectiveness evaluation would be suggested to be performed through cost–benefit analysis in order to prioritize conservation methods and spatial focus in the future.

Finally, it is worth noting that the findings of our study were based on limited data of two cases in Changting County. Future studies should investigate more study cases and expand to larger spatial areas to gain a more comprehensive understanding of the new approaches with respect to soil and water conservation.

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Author Contributions

Chengchao Wang collected the data and wrote the manuscript. Yaoqi Zhang provided valuable instructions on the structure and methods of the paper, and also greatly contributed to the manuscript revision, Yecheng Xu and Qichun Yang contributed to the manuscript revisions.

Conflicts of Interest

The authors declare no conflict of interest.

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