GREY GREEN STRUCTURES AS TREATMENT TO CLIMATE INDUCED DISASTERS:

A Cost Benefit Analysis of Grey Green Structures

Summary

Nepal as a mountainous country is highly vulnerable to the impact of climate change and specially, erratic rainfall patterns are observed in Nepal. Such scenario rainfall patterns along with degraded ecosystems will result in climate changed induced disasters i.e. flash floods, landslides, slope failures and erosion. Such disaster can result destruction of rural infrastructures i.e. roads, loss of property and even human lives.

The EbA Project has prioritized grey green or bio-engineer structures i.e. engineered structures supplemented by 'green' structures to address the losses from climate induced disasters and provide adequate protection. In Nepal, such structures are not new and have been in used since the early 1970's and have been pivotal soil conservation and management practices. Such structures have been adopted with the technical support from District Soil Conservation Offices and utilizing the traditional knowledge from local community.

This case study analyzes the contribution of such grey green structures put in place along with river bank of the Harpan Stream in Kaski District to protect the agriculture land at Ghatichhina. The result highlights that the stream would have ravaged 90 square meter of productive land annually had it not been constructed at the site while the economic analysis of the structure shows that it generates an NPV of NRs 506,600 over a period of 20 years including the benefits of avoided damage at Phewa Lake due to the reduced siltation in the dam while about 40 percent of the total cost is borne by these farmers, but the analysis shows that about 92 percent of the benefits accrue to the land owners.

Introduction

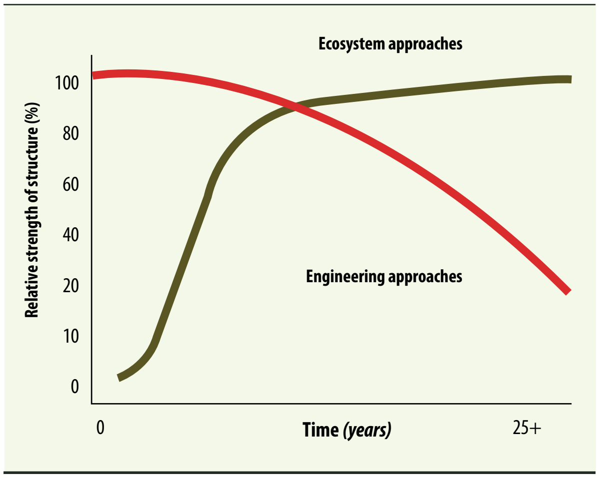
Ecosystem based Adaptation (EbA) was defined by the Convention on Biological Diversity (CBD) as "increasing the adaptive capacity of the population through the sustainable use and conservation of ecosystems". EbA is thus an anthropocentric approach which aims to increase human societies' resilience in the face of climate change by managing natural resources, sustainably and using them purposefully. This approach treats natural resources as complementary to or as a substitute for infrastructure measures. Ecosystem provides a range of goods and services to humans, many of which depend on processes and functions that would be difficult or impossible to replace. Ecosystem services are in essence an economic argument to protect biodiversity. They provide outputs or outcomes that directly and indirectly affect human wellbeing.

The living and non-living elements function together as an interdependent system, if one part is damaged, then, it impacts the whole system. The impacts of climate change on natural systems and their consequence on human welfare are already being felt at a global scale, and will likely intensify in the future. They could have serious implications on the functioning and the capacity of the ecosystems, and subsequently on those dependent on ecosystem services, at the global level. EbA addresses these crucial links between climate change, biodiversity, ecosystem services and sustainable resource management. The impacts of climate change are being felt by vulnerable ecosystems, leading to adverse effects on human wellbeing. EbA integrates the management of ecosystems and biodiversity into an overall strategy to help people and ecosystems adapt to the adverse impacts of climate change.

COST-BENEFIT ANALYSIS OF EBA OPTION

Cost-Benefit Analysis (CBA) is a method to evaluate the economic and financial feasibility of a proposed action which results in certain benefits and costs. It identifies potential direct and indirect physical impacts of an intervention, quantifies and values them in monetary terms across a relevant timeline and then evaluates

Relative strengths or effectiveness of Bio-engineering versus the Engineering approaches



them using specific tools like Net Present Value (NPV); the internal rate of return (IRR); and cost-benefit ratio (BCR). CBA estimates the cost of EbA measures and compares this with the benefits provided by the retained or the enhanced ecosystem services. If the benefits exceed the costs, it makes economic sense to invest further in these measures in the future. The overall net benefit or cost can then be compared with that of other options, or with the path of non-intervention. CBA, thereby, offers a relatively objective way to choose between various competing alternatives by weighing their relative costs and benefits. The results from CBA can be offered as an evidence for an optimal adaptation option that decision makers should invest in.

The present study is concerned with the CBA of bio-engineering (grey green) interventions in the Harpan River, mainly to control the loss of productive farm-land and subsequently reducing the rate of siltation in Phewa Lake. Another case study relates to the proposed construction of siltation dams in three sites. The dam constructions and the retention of the sand and silt are not truly an EbA measures. Nonetheless, the engineering measure has been taken into the account to assess its economic feasibility in the context of Panchase area, and the need to reduce sediment load in Phewa Lake. These dams have not yet been constructed but their engineering design and the construction cost have been estimated by FEED (P) Ltd in 2014. These dams are designed to store the silt and sand while the streams flow over them. Then, the silt and sand are annually removed to cater to the construction needs of Pokhara municipality. The value of the sand and silt is based on the prevailing market price of Pokhara. The effectiveness of the dams shall decline over the time, so shall the amount of extracted silt and sand. CBA under BAU scenario has not been carried out for these two case-studies, mainly because the returns from the EbA scenario far exceeds than from the BAU scenario.

Bio-engineering structure also generates high returns on investment and is also the effective and efficient means to protect valuable land and infrastructure against the ravages of torrents such as in the case of the Harpan Stream in Kaski.

Economic Analysis of Ecosystem Based Adaptation Options

CASE OF BIOENGINEERING RETENTION DAM ALONG THE HARPAN RIVER

Bioengineering at the Harpan River at Ghatichhina, is a green-grey approach taken as an adaptation measure to control the ravages being done by the fast moving stream, accelerated by the effects of climate change in the watershed area. Dry stones are stacked in a mat of gabion wire; and shrubs, trees or bamboos are planted on top of the stacked gabion wall. In comparison to the engineering approach, bioengineering (ecosystem approach) is more effective than the strictly engineering approach as illustrated in the figure below.

The trees or bamboos help support or anchor and reinforce the gabion structure on the ground, making it more effective. These bio-engineering methods have been constructed even by the local villagers to protect their private land against the ravages of the fast flowing stream. The type of inputs and their cost including the nature and the magnitude of the benefits from the very construction structure along the edges of Harpan Stream were estimated to discover the efficiency of the EbA in Panchase area.

EbA scenario of Bio-engineering intervention at Ghatichhina

The bioengineering structure annually saved about 90 sq. meter (45 meter in length and 2 meter in width) of prime agriculture-land lying at the either side of the Harpan Stream. If this structure would not have been made, annually about 54 cubic meter of soil (up to the depth of 60 centimeter) would have been eroded or deposited in the lake. This volume of soil is equivalent to an annual loss of 81 tons of soil from the farm, and its subsequent deposition in the Lake.

The cost of the bio-engineering structure comprises of the soil excavation, fabrication of gabion wire, setting the gabion boxes, transportation of materials from Pokhara to the site, filling boxes with stones, and bamboo plantation on top of the gabion wires. An additional 10 percent of these costs were added to derive the total investment cost of the structure. An annual maintenance cost of the structure was also estimated to arrive at the total cost of the initiative. Most of this cost was borne by the project, while about 40% of this investment cost was borne by the private farm-land owners. The recurrent cost has to be incurred each year and is totally borne by the private local owners.

Cost and benefit Analysis under EbA Scenario

The total investment cost of the bio-engineering structure, which incurred in the first year is NRs 651,231, out of which 60.8 percent is borne by the EbA project, and 39.2 percent is borne by the farmers. The recurring cost (NRs 25,000) which is incurred from the second year onwards is completely borne by the farmers. The life of the structure itself is estimated to last for 20 years.

The annual benefits from the investment comprises of private and external (social) ones. The private benefits of annually protecting the land (90 square meters) is NRs 141, 509, and the annual external benefit or avoided cost is NRs 12,555 or a total annual benefits of NRs 154,064.

A simple CBA was carried out to estimate the efficiency and cost effectiveness of the investment. A discount rate of 10 percent was chosen to carry out this analysis. A spread sheet analysis of the investment shows that the total present value of the cost was NRs 782,140, and the present value of benefits was NRs 1,288,737 over a period of 20 years. Thus, the benefit cost ratio is about 1.6. The Internal Rate of Return is 19 percent.

CASE OF ENGINEERING METHOD OF CAPTURING SILTATION: SILTATION DAM CONSTRUCTION IN HARPAN

Three engineering structures have been proposed to trap silt and sand carried by the Harpan Stream to reduce the siltation load in Phewa Lake. These engineering structures are not strictly the Ecosystem based Adaptation (EbA) measures, but they can be considered as one of the means of adaptation.

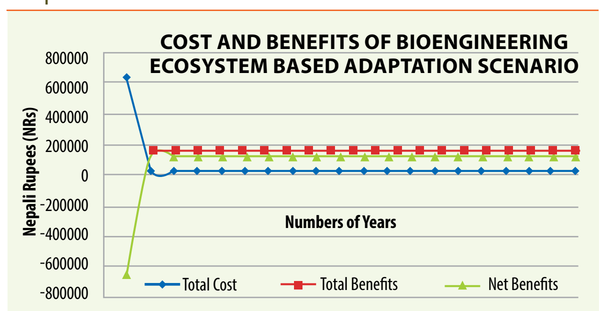
SUMMARY OF AREA, VOLUME AND COST ESTIMATE

S.N.	Description	Estimated Cost (NRs)	Retention (M3)	Area (M2)	Cost per Unit Capacity (Cu M)
1	Siltation Dam in Harpan Khola at Ghatichina	19,532,652	24,140	7,787	809.14
2	Siltation Dam in Khahare Khola at downside of Kerabari (Option 2)	40,909,027	143,812	39,727	284.46
3	Settling Pool at Harpan Khola at Kavre down side of Katre Suspension bridge	31,773,517	54,234	18,078	585.86
	Total	92,215,196	222,186	65,592	415.04

TARGETED SCENARIO OF SILTATION DAM CONSTRUCTION AT THREE SITES IN HARPAN

The life of the dams is assumed to last for 20 years because the effectiveness of engineering structure declines over time. We estimate that the effectiveness of the dams will be annually reduced by one percent in the first five years, by 1.5 percent in next five years, by 2 percent in the next five years, and by 2.5 percent in the remaining last five years. The design and the cost of these dams were prepared and estimated by FEED private limited company in 2014. Maintenance cost of these dams is also estimated based on the assumption that as the dams get older, they need more repairs, and so the cost of repairs (maintenance) would increase over time. Accordingly, the maintenance cost would be 10 percent of the construction cost at the end of the fifth year, 15 percent by the end of tenth year, and 20 percent by the end of 15th year.

Cost and benefit of bioengineering structure in Harpan Stream

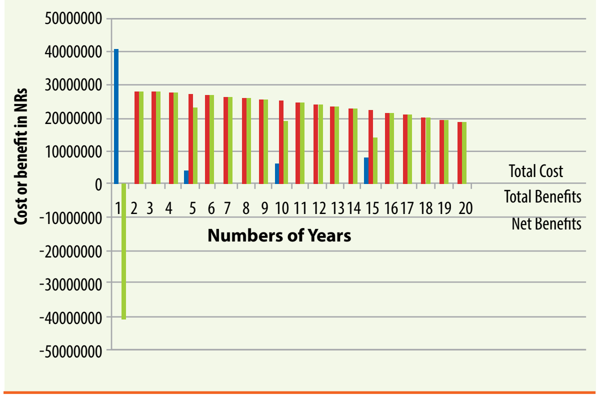


The benefits of the dam would comprise of revenue from the sale of silt and sand deposited in these dams, and the avoided cost of reduced siltation in Phewa Lake. It is estimated that annually about 70 percent of the silt/sand deposited in the dams would be sold at NRs 8 per cubic feet. This is the present market price of silt/sand in and around Harpan and Pokhara area. The external benefit of avoided cost is estimated to be NRs 155 per ton of silt/sand removed from these dams.

COST AND BENEFIT ANALYSIS UNDER TARGETED SCENARIO

The costs and benefits of all these options were discounted to carry out economic analysis. Economic analysis of Siltation Dams in Panchase is as given below in the figure.

Cost and benefit of a siltation dam at Khahare Khola



Sensitivity analysis of each of these options was also carried out to see the economic impacts of dam failure at the end of fifth and tenth years. The sensitivity analysis also shows that Siltation Dam at downside of Kerabari can still provide significant benefits if the dam fails even at the fifth year. Table below shows the NPV and B/C ratio for each of the siltation dam options proposed in and around the Harpan River. All of these analysis show that making a siltation dam in Khahare Khola at downside of Kerabari (option2) is the most economically beneficial option among these three investments.

Parameters	Siltation Dam in Harpan at Ghatich-hina	Siltation Dam in Khahare Khola at downside of Kerabari (Option 2)	Settling pool at Harpan downside of Kavre Suspension bridge
PV of Cost (NRs)	21,034,575	44,054,643	34,216,676
PV of Benefits (NRs)	32,649,426	194,506,182	73,351,656
NPV (NRs)	11,614,851	150,451,540	39,134,979
Benefit Cost Ratio	1.6	4.4	2.1
Sensitivity Analysis			
NPV: if dam collapses at year 5 (NRs)	(5,529,144)	40,341,295	(661,569)
NPV: if dam collapses at year 10 (NRs)	3,663,514	99,469,456	20,691,372

Policy Implications

Bioengineering is a traditional technique of protecting valuable paddy fields against the ravages of torrential streams in the mid hills of Nepal. As the intensity of rainfall is increasing over time due to the impacts of climate change, soil erosion and flooding would increase in the hills of Nepal. Farmers are willing to bear about 40 percent of the total cost of the structure which are more durable than the sole engineering structures. As the demand for these bioengineering structures would increase over time due to climate change, it would be useful to train and provide technical assistances to the local people to design and construct these structures in the rural areas of Nepal by themselves. The Government of Nepal has been spending significant amount of money on these structures in Chure area to protect the land against erosion on upstream and torrent control in the downstream.

Siltation dams are the unique engineering measures of adaptation against the ravages of sedimentation triggered by the drivers of climate change and other human interventions. These dams have not yet been constructed in Nepal. The economic analysis suggests that constructing these dams in some strategic locations such as at Kerabari would be very cost effective and efficient means of reducing sedimentation in Phewa Lake.

We recommend similar kinds of dam at Kerabari be replicated and constructed as a pilot project. Based on its experience modification of the siltation dams be made and replicated in other places such as at the foot hills of Chure hills, where the sediment load is even higher.

Conclusion

EbA intervenes into multiple sectors as agriculture, energy, water and infrastructure. It is therefore of utmost importance to harmoniously nurture the relationship between sectors managing ecosystem and local stakeholders who will be benefiting from the management.

By integrating EbA into the infrastructure sectors like building dams, and dykes based on conventional engineering approaches complimented with grey infrastructure, multiple benefits are generated. Other than the low cost, such infrastructures are ecofriendly and highly flexible to combat climatic adversities.

When a 45 meter long bio-engineering structure was constructed at Ghatichhina along the Harpan River in Kaski district, it not only saved the private land, but also reduced the rate of siltation that used to be deposited in Phewa Lake.

The stream would have ravaged 90 square meter of productive land annually had it not been constructed at the site. An economic analysis of the structure shows that it generates a NPV of NRs 506,600 over a period of 20 years including the benefits of avoided damage at Phewa Lake due to reduced siltation in the dam. The structure is constructed with cost sharing with the local land owners. As local stake-holders, their contribution is mainly labor-intensive. They also bear the annual maintenance cost. About 40 percent of the total cost is borne by these farmers, but the analysis shows that about 92 percent of the benefits accrue to the land owners. Thus, it is a very popular program in the area.

The three proposed siltation dams are designed and designated to trap silt and sand so that its deposition in Phewa Lake is significantly reduced. The dams' incurring costs have been estimated and its economic analysis have been carried out to see their economic viability before they could be built. The analysis shows that all of these dams would generate positive NPV. The Siltation Dam in Khahare Khola at downside of Kerabari (Option 2) generates the highest NPV. It also shows a NPV of NRs 40 million under the worst scenario of complete of rapture of dam by the end of 5th year.

Economic analysis (CBA) provides choices to decision makers, and helps to make decisions. It is also a means to devise various incentive mechanisms including reduction of perverse incentives. Bio-engineering structure also generates high returns on investment and is also an effective means to protect valuable land and infrastructure against the ravages of torrents such as Harpan stream in Kaski. A crude economic analysis of these three siltation dams shows that constructing a dam such as the one in Khahare Khola at downside of Kerabari is worth investing to reduce siltation and prolong the life of Phewa Lake.

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Technical Author:
Keshav Raj Kanel, Ph.D.: Natural Resource Economist.

Edited By:
Pragyajan Yalamber Rai & Pritisha Shrestha

For Further Information, Please Contact
Forestry Complex. P.O.Box.24417
Babarmahal, Kathmandu, Nepal
Tel: +977-1-4218458, Fax: +977-04225553
Web: www.dof.gov.np/eba

United Nations Development Programme
UN House, Pulchowk
G.P.O. Box 107, Kathmandu, Nepal
Tel: +977-1-5523200
Web: www.np.undp.org

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