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Climate change adaptation from small and medium scale hydropower plants: A case study for Lao Cai province

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Abstract. This paper presents an analysis of the benefits of climate change adaptation from small and medium scale hydropower plants in Lao Cai Province. Lao Cai is a mountainous province with high hydropower potential. Totally 116 small and medium hydropower projects in different stages of development have been identified with installed capacities ranging from 0.9 MW to 60 MW. Based on the results of statistic downscaling, four climate change scenarios were developed for the Lao Cai province area. Impacts of small and medium scale hydropower plants, both negative and positive impacts, on water resources, rural development, social economic and environment of the Province are assessed. The study also considers the benefits of small and medium scale hydropower plants on CDM revenues.

Keywords: climate change, adaptation, mitigation, small and medium scale hydropower.

1. Introduction on study area

Lao Cai is a poor mountainous province situated 300 km north-west from Hanoi. Its total area is 8,060 km^2 and in general the terrain elevation varies between 300 and 1000 m above mean sea level. However, some mountain peaks reach over 3000 m. Annual rainfall ranges between 1,400 mm and 2,900 mm. The population is 557,000 people, in which about 70% are ethnic minorities. Lao Cai is the province with poor population but high potential for small and medium scale hydropower development. The present case study has analyzed the effect of small and medium sized hydropower plants on the adaptation to climate change and the possible symbioses and trade-offs with rural development.

2. Research methodology

In this case study, the following methods were used:

(i) Document synthesis and data analysis;

(ii) Statistic downscaling and climate change scenarios development;

(iii) Field survey and investigation; and

(iv) Expert consultation.

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3. Results and discussion

3.1. Climate change in Lao Cai

Four different scenarios, as simulated by around 40 different Global Circulation Models and Atmospheric-Ocean Global Circulation Models, are used to assess climate change impacts in Lao Cai Province, namely: Baseline scenario using the historical data and simulating the climate during the period 1961-1990, low emission Scenario B1, medium emission scenario B2, and high emission Scenario A1FI. The results have been downscaled to give plausible results for the Lao Cai Province [1].

From the scenarios, it is seen that there is an increase in temperatures during the 21st century in Lao Cai Province. Mean annual temperature would increase about 1.3 to 1.7^{o}C by 2050, and 2.1^{o}C to 4.2 ^{o}C by 2100. Temperature rise is expected to be lowest in July (1.8^{o}C to 3.5^{o}C) and highest for the period November - March (2.2^{o}C to 4.5^{o}C). Annual rainfall also increases gradually over the 21st century, i.e. 15-17%, and 21-41% higher than the average value of the baseline period (1961-1990) by the year 2050 and 2100, respectively. Flood peaks and flood volumes with a given frequency would rise by 3-4% and 1-4%, by 2030, and 16% and 14% by 2100, respectively (Table 1).

Table 1. Changes in future flooding pattern

Estimated Flood Increases	Estimated Increase by 2030	Estimated Increase by 2100
Peak Flows	3-4%	16%
Flood Volume	1-4%	14%

3.2. Small and medium hydropowers system in Lao Cai

Totally 116 small and medium hydropower projects in different stages of development have been identified in Lao Cai Province, with installed capacities ranging from 0.9 MW to 60 MW. Among them, there are 3 projects having reservoir storages and only with regulation coefficients of 3.1%, 6.5% and 9.7%, respectively. The main part of the projects (78%) has an installed capacity of less than 10 MW while the average installed capacity for all 116 projects is 7.8 MW. The hydropower resources are not evenly distributed in the river basins in the Province with the main potential being in Ngoi Nhu River Basin with 37 identified small and medium hydropower projects.

Simple economic evaluations show that if the value of energy would be 5 UScent/KWh, all 116 identified projects but one would be economic viable, not an unrealistic assumption with current prices for fossil fuel.

The estimated demand in Lao Cai Province in 2010 and 2015 are 663.5 GWh and 1,357 GWh, respectively, the peak demand for the same years are 146 MW and 271 MW, respectively. Assuming that all projects under construction and in an advanced stage of design would be commissioned by 2010 and that all projects being registered would be commissioned in 2015, the projects can cover the energy demand in 2015 for all months apart from February and March (with a maximum deficit of 5.9 GWh in March). The peak power demand cannot be covered by the identified small and medium hydropower projects for December to April in 2015, and the maximum deficiency amounts to 125 MW in 2015. The energy and peak power deficits need to be imported from outside of the province, while surplus energy may be exported with a total of at least 1.8 TWh/year in 2015 [2].

3.3. Impacts of small and medium hydropowers system to natural resources, environment and social economics rural development

3.3.1. Impacts to natural resources, environment

a) Environmental aspects

An overall assessment of potential environmental impacts is conducted for three representative basins, including 17 hydropower projects. Construction of hydropower will affect the terrestrial ecosystems at the project sites and the surrounding areas. Most of the ecosystems at the project sites are very poor with scattered vegetation cover.

The identified projects are designed to release water from the reservoir to downstream power house, and in some cases, to a nearby river basin, implying that unless compensation flow releases from the dams are enforced, river reach between the dam and the power house is dry or almost dry during the dry season. For the 17 investigated projects in Ngoi Bo, Ngoi Xan and Suoi Chut rivers, the potentially dry river reaches are amount to 48.5Km. It seems that the given energy production of the identified projects do not include environmental flow to mitigate impacts on the downstream aquatic ecosystem, biodiversity and human activities. If environmental flow, defined as the 90% probable average flow during the three driest months every year, is adopted, the reduction in energy production for the identified projects is estimated at nearly 10%. This reduction will have consequences on the economic viability of the projects and only 80 (69%) of the identified projects, with a total installed capacity of 721.3 MW (80%) and an average annual energy production of 2,816 GWh (72%), would in that case be economically viable [3].

b) Water allocation and conflicting demands

The conflicting demands from various water users in the three focus basins are scrutinized and modeled. The simulation results show that it would be possible to meet downstream water demands and of the environment by releasing a certain amount of flow to the river. The implications for the power production of such compensational flows is as stated above.

3.3.2. Effects of hydropower projects on climate change adaptation and mitigation

Effects of hydropower projects on climate change adaptation and mitigation can be summarized as follows: (1) Climate change mitigation related to reduction of greenhouse gas (GHG) emissions by replacing thermal power production; Climate change adaptation related to changes of the hydrological pattern with increased floods, such as increased occurrences of flash-floods, that may be alleviated by storage capacities of reservoirs; (3) Climate change adaptation related to changes of the hydrological pattern with more pronounced dry periods that may be alleviated by release of water stored in hydropower reservoirs during dry periods giving positive effects on downstream water supply and irrigation.

a) Mitigation effects

Regarding climate change mitigation, two alternatives are investigated as follows:

Alternative 1: Assuming that power produced by the plants will alternatively have to be generated from coal fired plants, a yearly GHG emission of 4.28 million tons may be avoided by implementing all the 116 identified small and medium hydropower projects in Lao

Cai Province assuming no environmental flow, compared to 3.12 million tons/year if environmental flow is adopted on the remaining 80 economic viable projects, i.e. a difference of 1.16 million tons/year. Hence, there is a trade-off to be considered between producing more climate neutral energy and conservation of the local environment. GHG emission from the reservoirs represents only some 0.2% of the avoided greenhouse gas emission from the coal-fired thermal plants, and can therefore be neglected.

Table 2. Yearly Avoided GHG Emission for Different Development Scenarios.

Scenarios	**Outline**	**Number of Projects**	**Total Installed Capacity MW**	**Total Energy GWh/year**	**Total Avoided GHG Emission Million Tons/year**
1	Existing + projects under construction	26	396.8	1,662.1	1.78
2	Scenario 1 + projects in advanced design stage	43	551.3	2,290.4	2.46
3	Scenario 2 + registered projects	61	738.6	3,134.2	3.36
4	Scenario 3 + non-committed projects	121	928.6	3,990.5	4.28

Alternative 2: This alternative considers only economically and financially viable projects with and without CDM funding and using a baseline emission factor of 588 tons CO2/GWh (average for the Vietnamese grid). In this alternative, a yearly GHG emission of 3.45 million tons may be avoided by implementing all the 85 financially viable (with CDM revenues) hydropower projects, compared to 2.24 million tons by implementing the 45 financially viable (without CDM revenues) projects, i.e. a difference of 1.21 million tons/year. If all 30 projects, i.e. excluding existing and projects under construction, that become financially viable due to carbon credits are implemented an additional yearly GHG emission of 1.0 million tons may be avoided.

Table 3. Yearly Avoided GHG Emission for Different Development Scenarios of Financially Viable Projects with CDM Revenues.

Scenarios	**Outline**	**Number of projects**	**Total installed capacity (MW)**	**Total energy (GWh/year)**	**Total avoided GHG emission (Million Tons/year)**
1	Existing + projects under construction	23	380.0	1,598.2	1.71
2	Scenario 1 + projects in advanced design stage	33	464.2	1,935.2	2.08
3	Scenario 2 + registered projects	48	600.6	2,578.4	2.77
4	Scenario 3 + non-committed projects	85	739.2	3,219.1	3.45

b) Adaptation effects

Low flow augmentation: It is seen that only one plant in the Province (Seo Mi Ty) has sufficient storage to augment low flows. This effect is localised, at the first downstream confluence with the larger Ngoi Bo River the effect is negligible. Another plant under construction in the Province has a larger regulating effect, but since this is classified as large hydropower plant. The planned small and medium sized plants in the Province will consequently not have any low flow augmenting effects.

Flood alleviation effects: Due to lack of active storage capacity, none of the planned small and medium hydropower projects in the Province have flood alleviating effects**.** The physical effect of the considered plants on climate change adaptation by flood alleviating is therefore negligible.

Estimated production under future climate condition

If environmental flow to be provided, average increase in energy production relative to the present hydrological conditions is larger, and it is estimated at 7.7% for 2030 and 12.1% for 2050 for Scenario B1, 6.3% for 2030 and 10.1% for 2050 for Scenario B2, and 6.2% for 2030 and 13.5% for 2050 for Scenario A1. The corresponding additional yearly avoided GHG emission due to climate change is estimated at some 200,000 and 400,000 tons for 2030 and 2050, respectively, by implementing all the 85 small and medium hydropower projects being economically viable with environmental flow.

3.3.3. Rural development aspects [4]

Impact assessment is carried out following the guidelines of OECD an ‘Ex Ante Poverty Impact Assessment’. The method is applied to summarise the process by which the intervention is expected to influence stakeholders (targeted and others), and to assess the overall result anticipated by each of the main transmission channels which are: prices, employment, transfers, access, authority and assets.

Important aspects of the potential positive or negative effects on rural development are future government policies on subsidies for electricity, both connection fees and per KWh. Likewise, the development of the electricity market, and whether EVN’s monopoly will be changed to an open market with possibilities for local hydropower plants to set their own tariffs for local networks, will to large degree determine the effects of the hydropower plants on rural development.

a) Impact on economic capabilities

Assuming a water resource tax rate of 2% at a fixed rate of 700 VND/kWh, the developers of the 58 plants shall pay about 29,4 billion VND of water tax. It cannot be estimated how much of these taxes will benefit Lao Cai Province directly.

In the short term, during construction, contractors will buy various construction materials and businesses/trade households are likely to benefit from hydropower development. In some of the projects already under construction a substantial number of local workers have been hired for salaries substantially higher than the average wages in the area. Many workers are recruited in the construction stage but only a few when they come into operation.

On the negative side local farmers upstream, near the construction sites and near roads to the hydropower plants can be losing because of land loss, degradation of natural resources, and impacts on water and air environment. Although they receive compensation, recovery of their economic production will take time. Fishing farmers can lose income from fishing along rivers as consequence of pollution during the construction phase and flow diversion during the operation phase, and due to blocked fish migration.

In the medium term, most stakeholders can get benefits from hydropower development because of continuously supplying services to the operation of the hydropower plants and workers. Local farmers can have more opportunities to develop their economy provided they get access to reliable and affordable electricity. However, farmers living along the part of river between the dam and the power house will likely be deprived of fishing in the river, and can experience lack or shortage of water for electricity generation by micro-generators.

b) Impact on human capabilities

In the short term, local workers can have a chance to improve their knowledge/skills for future work; while local farmers living between the dam and power station, and households near the road to the hydropower development can suffer a reduction in food security and in nutrition sources because of reduction of rice and fish productivity.

In the medium term, most stakeholders will have better access by road, and thereby to information and public services (medicine, education, etc.), so their human capability can be improved. Local farmers living between the dam and power station will likely continue to be negatively impacted.

c) Impact on political capabilities

Generally, local farmers are involved in community consultations on issues related to their life and assets in the design phase. They also actively participate in negotiations on compensation of assets, farming production, etc. Thus, their political capability could be improved in the short and medium term allowing them to participate more actively on public issues.

d) Impact on socio-cultural capabilities

In the short term, many outsiders will come to the region and new relationships between them and local people will be established. The presence of outsiders will cause socio-cultural disturbances among ethnic minorities and may introduce or exacerbate some diseases. However, in the medium term, those effects are likely to disappear and no serious impacts are expected on this dimension.

e) Impact on protective-security capabilities

In the short term the vulnerability of local people seems to be increased because food security for some households through fishing and collecting aquatic organisms may be reduced, or rice fields are lost or affected by hydropower/road construction.

In the medium term, however, the economic and human capabilities of most local people could be improved as direct and indirect effects of hydropower development. Their vulnerability could be reduced and they can easier withstand economic or natural shocks.

In the future, according to the analyzed climate change scenarios, more rainfall is likely to occur, implying that flash floods, rather than droughts, may become a more serious problem for the local people to deal with. However, flash floods occur due to high rainfall, on near saturated soil in steep terrain, and construction of the hydropower plants are not likely to protect against these factors.

Based on these assessments a scale of positive and negative impacts in the short-term and in the medium term has been applied.

4. Conclusions and recommendations

Recommendations can be drawn from the study as follows: (1) Lao Cai is mountainous provinces with high hydropower potential. Totally 116 small and medium hydropower projects in different stages of development have been identified, with installed capacities ranging from 0.9 MW to 60 MW; (2) yearly GHG emission of 4.28 million tons may be avoided by implementing all the 116 identified small and medium hydropower projects in Lao Cai Province assuming no environmental flow, compared to 3.12 million tons/year if environmental flow is adopted on the remaining 80 economic viable projects, i.e. a difference of 1.16 million tons/year. (3) Transparency, access to information and proactive information dissemination on both positive and negative impacts of the projects from the investor and the provincial and local authorities must be ensured; (4) Adherence to the policy relating to land clearance approved by the government and the People’s Committee of Lao Cai Province to minimize negative impacts on households losing residential, agricultural, forest land etc., and to avoid conflicts between the project investor and local people; (5) Ensure that negative effects on the environment and especially the aquatic environment are mitigated as much as possible; (6) Use as much as possible local labor resources for work in the project; (7) Work force recruited from outside should only be for technical, monitoring and managing positions; (8) Register the residence of workers and their families to help the local authority to manage the work force and security in the project area; (9) Educate the workers on their duty not to encroach and discriminate local customs, tradition and habits; (10) Organize seminars on new policies and regulations to help workers and local people understanding this context, (11) Projects should support local construction of health service stations, schools, roads, water and electric providing systems; (12) Use of standard quality approaches to resettlement; and (12) Technical training for local people to work in projects.

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