Impacts of floating solar panels: the Magat reservoir as reference case

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Presentation outlook

- Project and research questions
- *The Magat case study reference*
- *Approach to the ex-ante impact assessment*
- Predicted impacts on the environment, socio-economic and socio-cultural aspects
- Measures to enhance co-benefits and reduce adverse impacts
- Some discussion & reflections

Photo credits, SNAP 2021.

The Hydrosun project, background

- The Hydrosun project (2021 -2024) aims to develop the required competence base for development and operation of hybrid hydro - floating solar panel power plants.

- It is a collaboration between five research institutions and six renewable energy companies.

- Few studies based on primary data collection on the impact of floating solar panels exists. FPV coverage may have **positive** or **negative** impacts depending on changes in evaporation, water temperature, oxygen, light penetration, and productivity.

The project studies the impacts of floating solar panels on the environment and on society.

Purpose & Research questions

Purpose: For transition and transformation of society for sustainable & renewable energy provision address environmental, socio-economic, and socio-cultural aspects of floating solar panels / floating photovoltaics (FPV).

The following research questions are addressed:

1. How does FPV impact the natural environment (direct impacts)
2. How does FPV impact economic and socio-cultural aspects (direct and indirect impacts)
3. Identify mitigation activities to reduce negative impacts and enhance co-benefits.

Selection of case study reference for the study, criteria : Existing hydropower operations: Access to data i.e. area, depth, hydrology, water temperature. Local institutions and actors available for contact.

Magat reservoir case study

Magat is a multipurpose dam constructed between 1975- 1982 for irrigation, flood control and power generation - a 388 MW HPP.

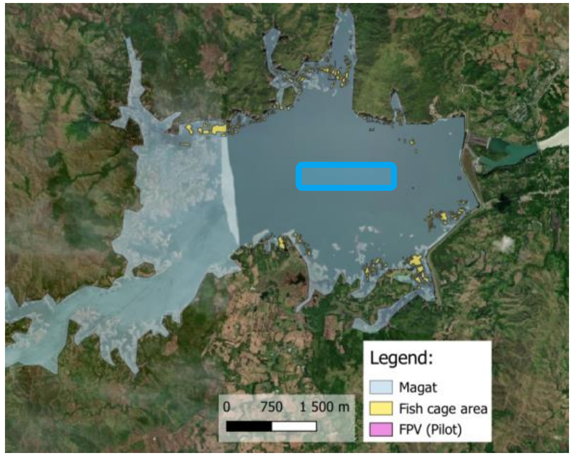
Priority of the water use is for irrigation downstream of the dam.

A 280-kWp FPV pilot was installed on the reservoir in 2019.
A 24 MW chemical battery with 32 MWh storage capacity to utilize flexible and advantages of FPV and battery in 2023.

There are plans to expand the pilot FPV to commercial scale.

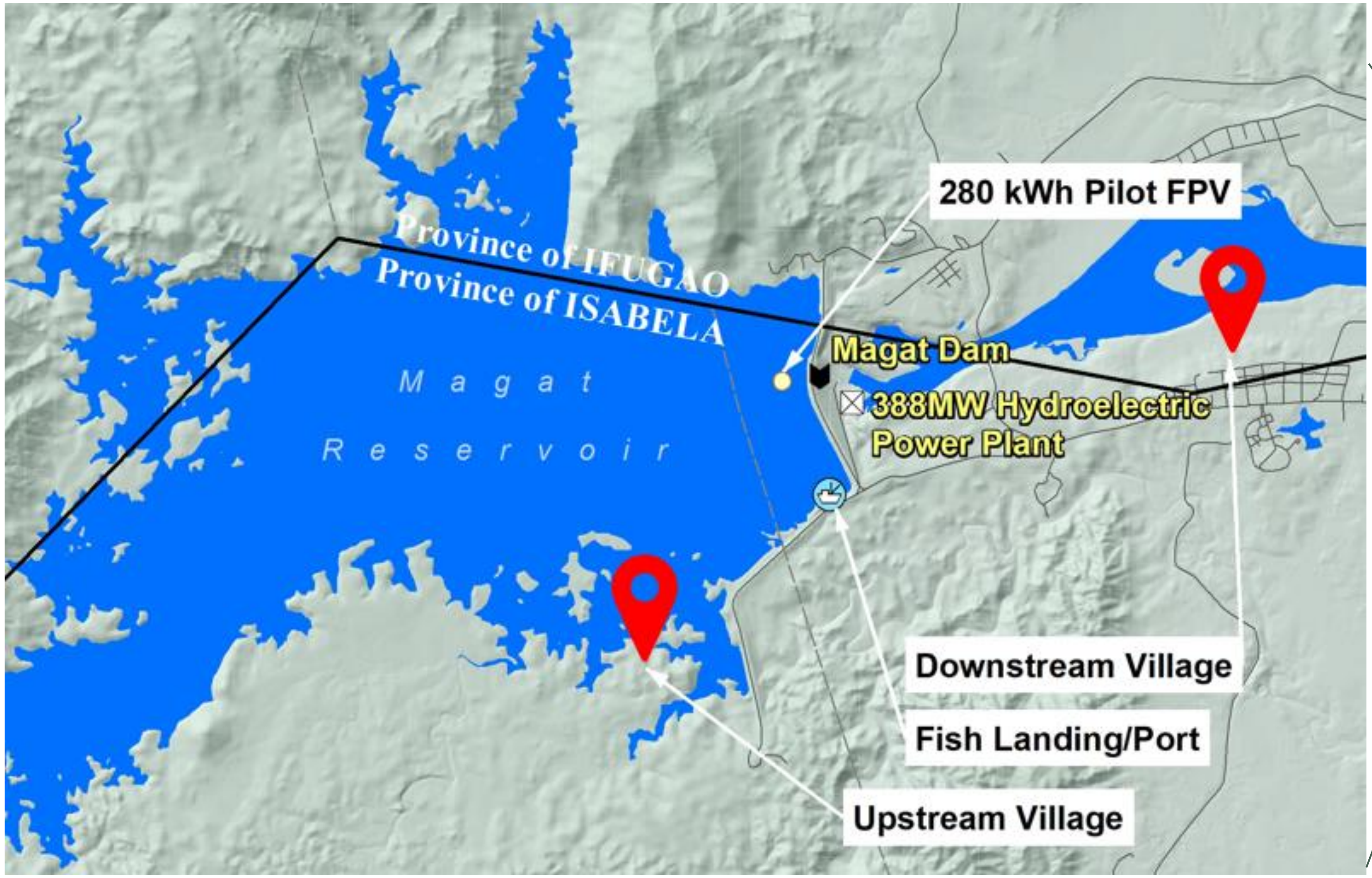
Magat reservoir & HEP (SNAP, 2020)

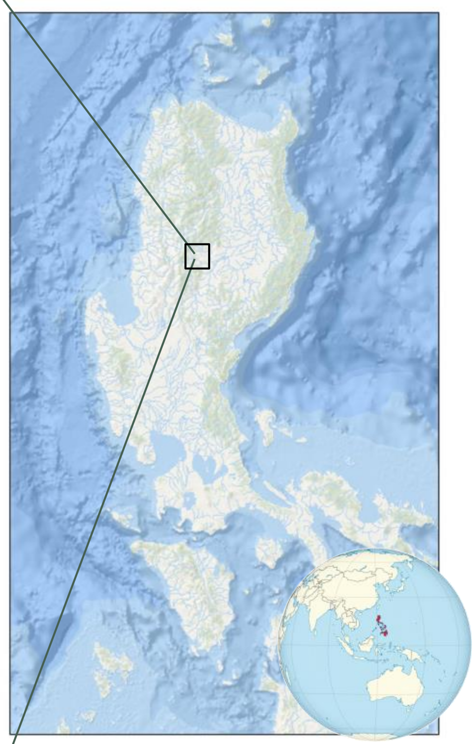
The pilot FPV on Magat (Nesheim, 2021)



Supposed set up of commercial scale (Clayer, 2023)

The Magat reservoir





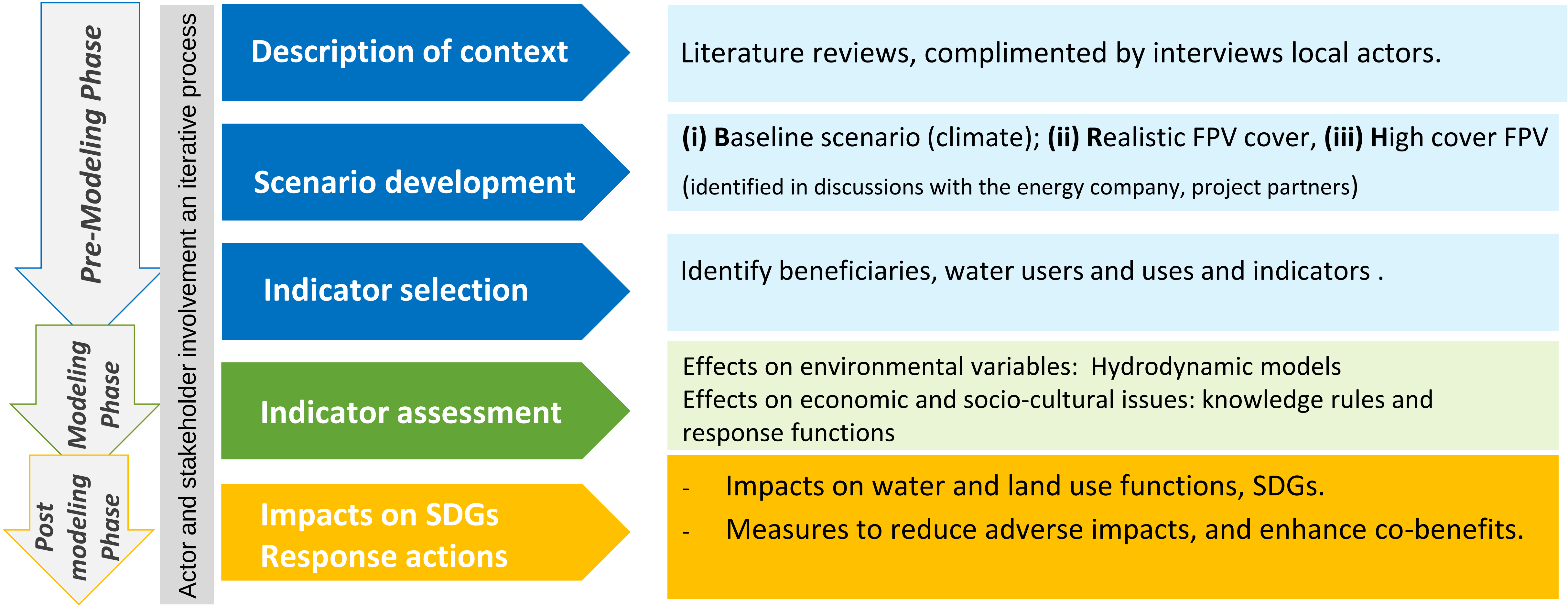
Size of reservoir 15–25km^2

The maximum depth: 60 meters.

Number of people in the watershed is approx. 1,1 million

The Magat Forest Reserve covers large parts of the watershed.

Conceptual framework for ex-ante impact assessment

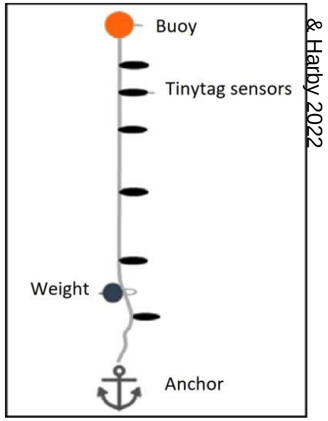


Adapted from Reidsma et al., 2011 (Land Use Policy 28, 604-617.

Primary data collection

Data collection	**Environmental aspects** (*2 collection points*)	**Economic and socio-cultural issues (*upstream & downstream)***
2022-2023, hourly	Temperature below FPV and open water	Water users and uses identified (Map based approach with villagers)
2022, June	Temperature profiles, Dissolved O2,	Indicators to represent water users and uses identified (Focus group discussion with villagers)
2022, November	Temperature profiles, Dissolved O2	
2023, June	Temperature profiles, Dissolved O2, water samples nutrient	Local authorities (Identify measures to enhance co-benefits and reduce adverse effects


Nesheim, 2022



Håll, 2022 (adapted from Adeva-Bustos & Harby 2022


Nesheim, 2022


SNAP, 2022

Indicator framework to investigate effects

Sustainability Dimension	Water and Land use Functions	Beneficiaries, Actors
Environmental dimension	**Provision of water availability**	Responsible authorities local regional and national level, NGOs, civil societies (upstream, downstream, indigenous people).
	Provision of good water quality	
	Biodiversity and biotic resources	
	Climate change mitig., GHG em.	
	Ecosystem processes	
Economic dimension	**Industry and physical production**	Industries, companies, households,
	Provision of employm. & income	Provincial and local government authorities, civil soc.
	Provision of electricity	National authorities, Energy company, industries
	Infrastructure for transportation	Aquaculture and local fisherfolks, local transport
	Flood control	Local, provincial authorities, Farmers, downstream dwellers
Socio- cultural dimension	**Food, Security, Livelihood**	Local government authorities
	Recreation and Quality of life	Villagers recreation – scenery, boating, swimming
	Social cohesion	Different groups of people – relationships
	Cultural heritage	Responsible auth. Indigenous people, Villagers cultural heritage – fluvial parades, cleansing, baptism, *gulgul*

The indicator framework ensures holistic assessment

Adapted from Reidsma et al., 2011 (Land Use Policy 28, 604-617.

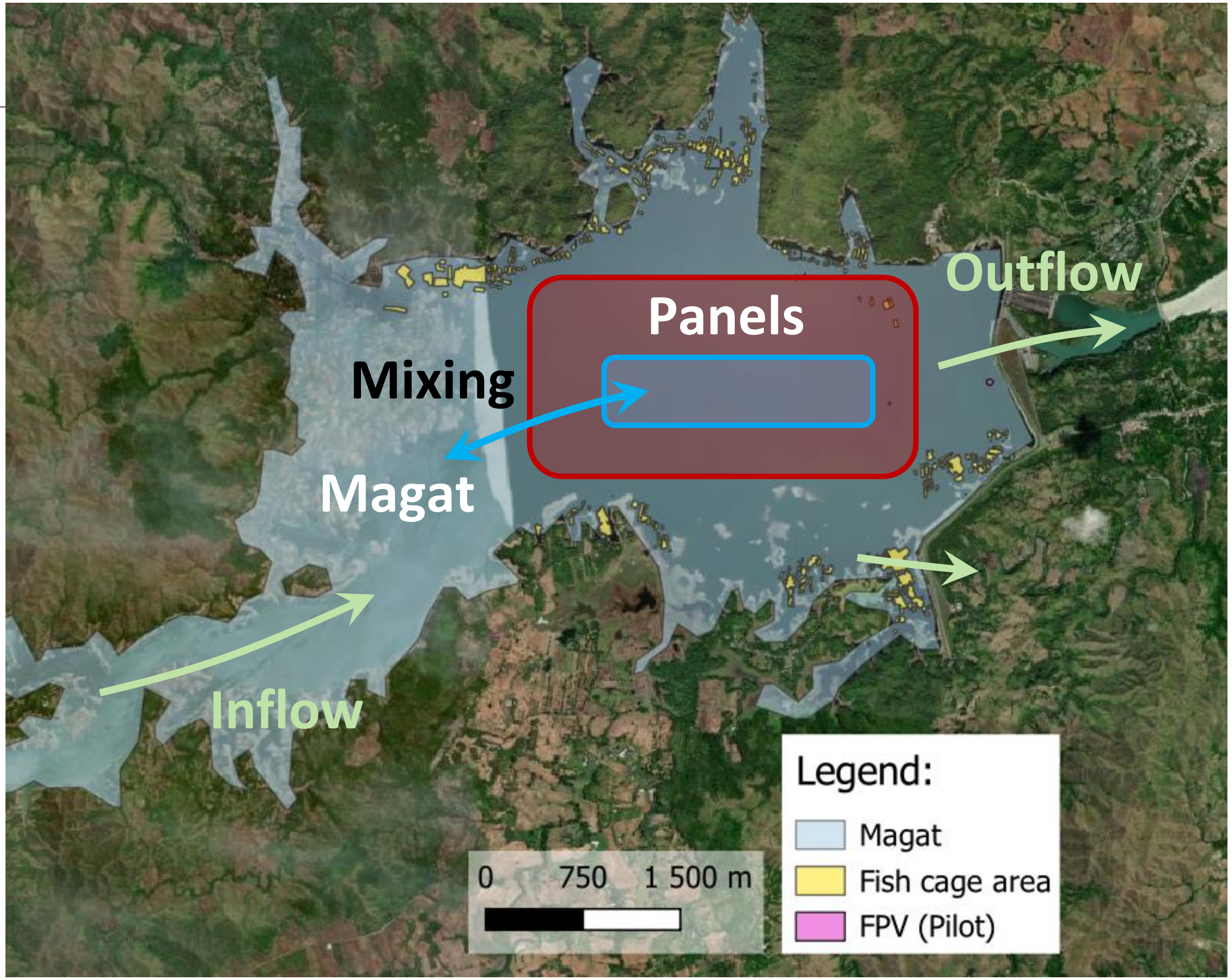
Scenarios for the impact assessment

3 Scenarios

Baseline
- No FPV

Indicative commercial scale
- FPV in the middle

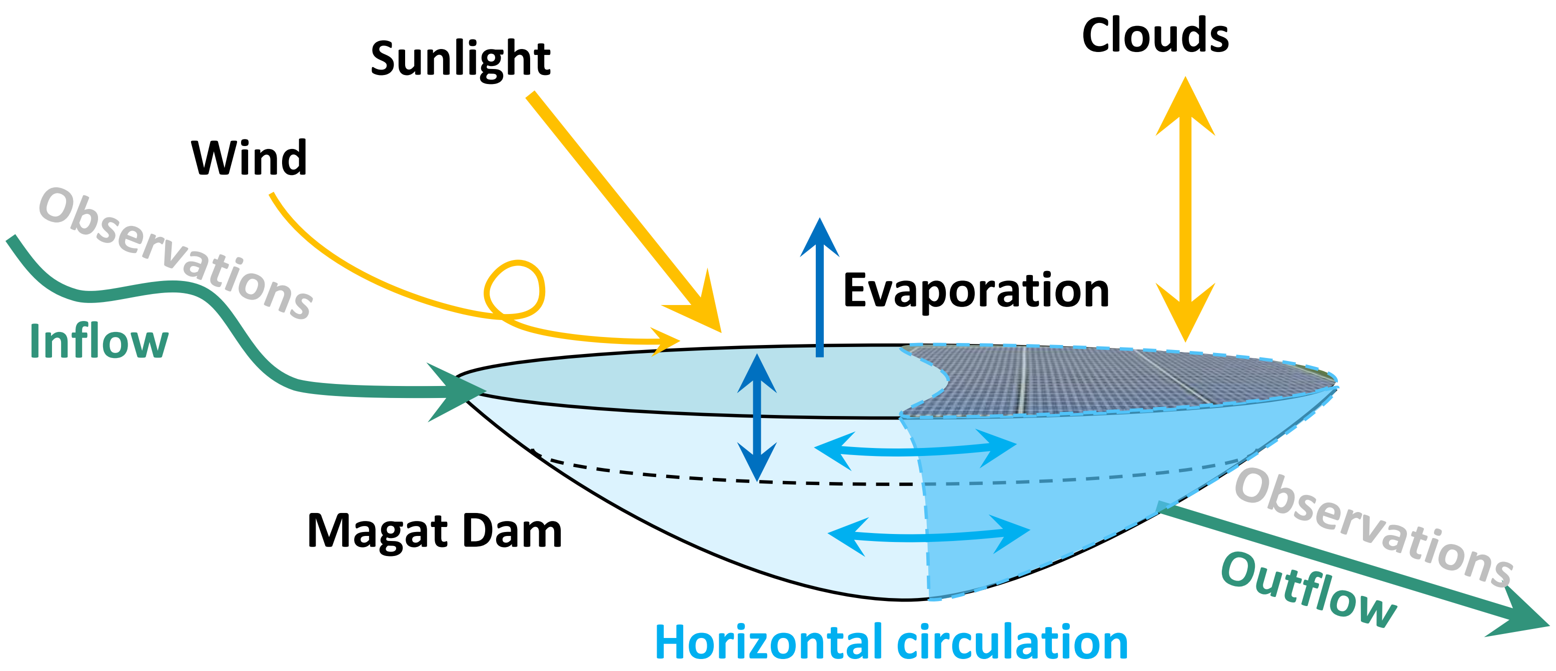
Unrealistic large coverage
- FPV in the middle



Representation in the model:

- Two basins: «Magat» and «Panels»
- Inflow to «Magat»
- Outflow from «Magat»
- Variations in horizontal mixing

Hydrodynamic model for the environmental assessment



Model outputs for validation:

- Water level
- Water temperature
- Oxygen and nutrient concentrations

Impacts of FPV on surface:

- Evaporation
- Heat exchanges Lindholm et al. (2022)
- Light penetration
- Gas exchanges (O_2, CO_2 and CH_4)

Predicted impacts during extremes

Worst case scenario: lowest horizontal mixing with FPV cover

	Thresholds	Impacts	Numbers of days/year Baseline	Commercial	Unrealistic
Oxygen	< 5 mg L^{-1}	Small on growth			
	< 3 mg L^{-1}	Strong on growth and reproduction			
	< 1 mg L^{-1}	Death within hours			
Temperature	> 35°C	Small on growth			
	> 37°C	Strong on growth and reproduction			
	> 42°C	Death within hours			

Sources: Pandit & Nakamura (2010) El-Hack et al. (2022)

Best case scenario: Highest horizontal mixing with FPV cover

- **No change for Tilapia**

To avoid harmful impacts on Tilapia, might need some interventions to increase circulation

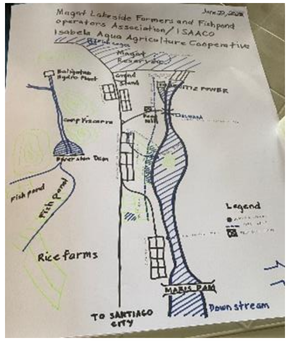
Map based approach to identify economic and socio-cultural beneficiaries

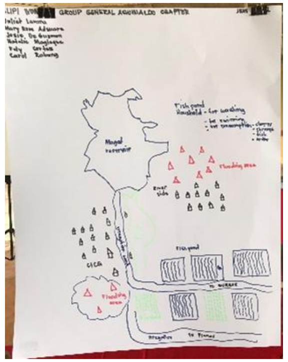
Upstream Village

Water users / uses	Ranking
Energy company	High
Solar power generation	
Aquaculture farmers	
Fishing for sale, subsistence	
Boaters / transportation	
Tourism	Intermediate
Farmers (irrigation)	
Recreation	
Cultural heritage festivals	Intermediate - low
Domestic water usage	
Cultural heritage religious events	

Downstream Village

Water users	Ranking
Farmers - irrigation	High
Fish pond farmers	
People fishing in channels for sale , subsistence	Intermediate
Domestic water usage	
Tourism boating	
Recreation, swimming,	
Recreation boating	Intermediate - low
Cultural heritage festivals;	
Religious events	





Key expected positive and negative impacts

Sustain ability	Water and Land use Functions	Baseline	Indicative commercial scale	Unrealistic large coverage
Environmental Dimension	Provision of water availability Provision of good water quality Biodiversity and biotic resources Climate change mitigation, GHG emissions Ecosystem processes	More frequent hypoxic events due to climate change (low level, high temperature)	During weather extremes, **Some negative effects – increased temperature and hypoxia**	**Positive impact: reduced evaporation - more water** During weather extremes, **More negative impacts hypoxia and increased temperature , reduced biodiversity**
Economic dimension	Industry and physical production Provision of employment and income Provision of electricity Infrastructure for transportation Flood control	Fish sanctuary (1km from dam) - if enforced negative impact on aquaculture farming	**Some positive impacts: employment opportunities, security of energy supply & flexibility, ancillary services.** **Some negative impact: Reduced aquaculture production, increased transportation costs & time**	**Positive impact: employment opportunities, energy production, flexibility & storage, ancillary services; flood control** **More negative impact: Reduced aquaculture production and fishing yields. Reduced transporation by boat & increased transportation costs & time.**
Socio-cultural dimension	Contribution to food security Recreation opportunities and quality of life Cultural heritage (not addressed)	No significant changes expected.	**Positive impact: The FPV interventions can be used for education purposes.** **Some negative impact: Reduced opportunities for recreation, boating.**	**Positive impact: The FPV interventions can be used for education purposes.** **Negative impact: Reduced opportunites for recreation on the reservoir, boating, reduced subsistnce from fishing, inconvenient transporation opporutinties and increased costs.**

Activities to mitigate adverse impacts and enhance co- benefits

<table>
<tr><th>Water and Land use Functions</th><th>Examples of Measures to Enhance Co-Benefits</th><th>Measure to Reduce Adverse Impacts</th></tr>
<tr><td>Provision of water availability</td><td rowspan="5">Water quantity - realizing co-benefits depend on dam operation regime.</td><td rowspan="2">Ventilation below the panels to reduce hypoxia</td></tr>
<tr><td>Provision of good water quality</td></tr>
<tr><td>Biodiversity and biotic resources</td><td rowspan="3">Allow and optimize open area between panels</td></tr>
<tr><td>Climate change mitiga. GHG em.</td></tr>
<tr><td>Ecosystem processes</td></tr>
<tr><td>Industry and physical production</td><td colspan="2" rowspan="2">Employ local residents</td></tr>
<tr><td>Provision of employment and income</td></tr>
<tr><td>Provision of electricity</td><td colspan="2">Construct new port with cold storage</td></tr>
<tr><td>Infrastructure for transportation</td><td rowspan="2"></td><td rowspan="2">Consider enough room for boats to navigate between panels</td></tr>
<tr><td>Flood control</td></tr>
<tr><td>Food, Security, Livelihood</td><td colspan="2" rowspan="2">Educational trip related to FPV</td></tr>
<tr><td>Recreation and Quality of life</td></tr>
<tr><td>Cultural heritage</td><td></td><td>Consider enough room for boats to navigate between panels</td></tr>
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Summarizing reflections

- Hybrid hydro- floating solar panels allows for flexibility in energy production by less dependence on weather.
- Solar panels on water - not on land reduces land area use conflict. In Magat the watershed is a forest-reservation area.
- FPV -environmental impacts: reduction in evaporation rate, but also reduced oxygen levels
- For a multipurpose use lake / reservoir covering the water with panels will compromise other uses.
- **Sustainable FPV is possible with mitigation activities -** optimal placement of the FPV and ventilation below – to avoid hypoxia, and to allow navigation between panels.

Let's continue the conversation!

Post questions and comments in the IAIA24 app.

Snap, 2022

Nesheim, 2023

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