



Making space for Philippine rivers

Introduction

The Philippines is prone to hydrometeorological hazards, including floods, landslides and riverbank erosion. Embedding fluvial geomorphology, the study of the origin and evolution of river landscapes, into policy and practice is essential to achieve catchment-scale visions of sustainable river management.

Framing the Problem

A river's shape is the result of sediment erosion, transport and deposition, which are a consequence of water flow. Natural events (e.g. typhoons, earthquakes, volcanoes) and anthropogenic impacts (e.g. sand/gravel quarrying, riverbank protection) cause variation in sediment supply, which drive change in riverbed levels. These changes influence flow routing, and thus flood risk. The same factors determine variations in bank erosion rates; elevated rates result in the loss of developed floodplain and the failure of critical infrastructure such as road bridges. In the Philippines, rivers are particularly dynamic; risks arising from changes in a river's bed and bank position need to be assessed and incorporated into river and flood risk management to mitigate the impact on people's welfare and the economy.

Executive summary

This project developed tools and approaches that incorporate geomorphic principles towards sustainable river and flood management that recognises river diversity and supports practices that 'work with the river'.

Key research findings

Our work found differences in the character, behaviour and evolutionary trajectory of river systems in the Philippines. As yet, understanding of this diversity isn't often used to inform river and catchment management.

Our work showed how different rivers in different parts of the Philippines require different amounts of space as they adjust in different ways.

We developed simple equations to estimate flood volumes based on catchment size and regional location.

Findings from several case-study rivers showed how repeat topographic surveys can be used to quantify and explain channel change. This approach could be used to achieve sustainable sand and gravel quarrying.

We showed that flood maps need to be updated in catchments where there is significant river channel change.

We recommend incorporating our tools and approaches to enable and prioritise more sustainable management of Philippine rivers, in ways that will reduce disaster risk and improve the health of river ecosystems.



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Research approach

Bringing together river scientists, geomorphologists, hydrologists and remote sensing specialists, the project has undertaken research activities that deliver evidence-based solutions to river and flood management challenges. Activities have been completed at the national-scale and in selected case-study river systems, including: (i) the Bislak River (Ilocos Norte) and, (ii) the Pinacanauan de Ilagan River and two of its tributaries the Abuan and Bintancan Rivers (Isabela).

Research activities included:

A nationwide assessment of river catchment characteristics. We used a nationwide digital elevation model (DEM) to calculate stream network and river catchment properties for 128 medium- to large-sized catchments (drainage area > 250 km²). This information can provide place-based understandings to contextualize the diversity of river systems.

Detailed topographic surveys of river channels and floodplains. Repeat airborne LiDAR for the case-study rivers were used to quantify morphological change at annual and multi-year timescales. The topographic datasets provided new insights into the rates and spatial patterns of geomorphic processes.

Updating flood hazard maps to account for morphological change. Using the newly acquired topographic datasets, we investigated how morphological change impacted flood risk. We ran flood models to produce updated flood maps that showed inundation extent, depth and hazard, consistent with existing flood mapping guidance.

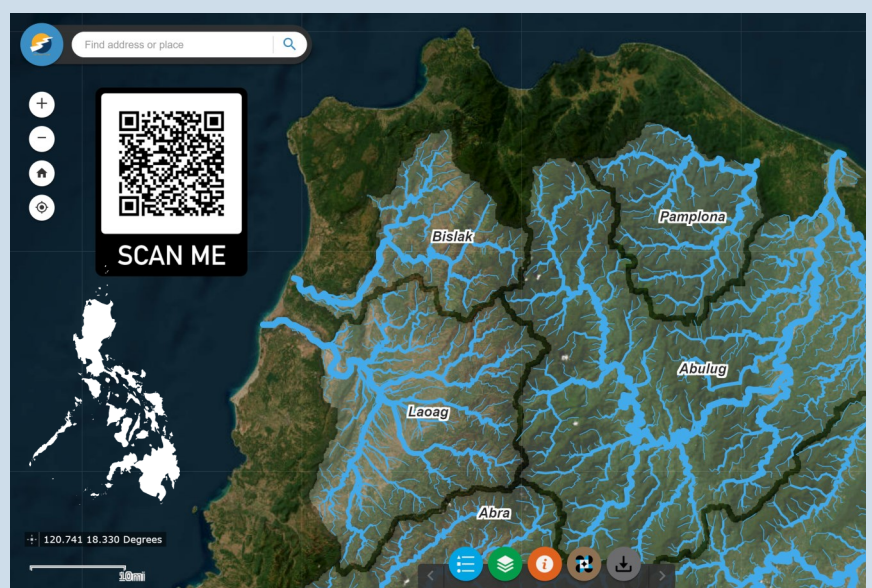
River channel mobility analysis. We analysed more than three decades of satellite imagery to map and measure river channel mobility. For ten of the largest rivers in the Philippines, we assessed typical river behaviour and identified which parts of the river system were most prone to different types of river channel dynamism.

Hydrology analysis. Statistical analysis of river flow records from more than 450 gauging stations across the country were used to derive new estimates of flood magnitude and frequency that can be applied in ungauged catchments.

In summary, river and flood management needs to adopt a catchment-based approach. Place-specific knowledge is needed. Learning from a river's shape and its dynamics, and giving it space, will support sustainable management practices.

Case study (1) National-scale geodatabase of river catchment characteristics

Effective river management requires an understanding of the resource that is being managed. A systematic assessment of stream network and river catchment characteristics was undertaken at the national-scale to show the diversity and distinctiveness of Philippine river systems. We displayed the results in an interactive web-application that enables anyone to freely access, explore and download the data (scan the QR code or visit <https://tinyurl.com/PHCatchmentDatabase> to view). The geodatabase provides data to support geomorphological, hydrological, water resource and natural hazard management applications. Read the full paper here: <https://doi.org/10.1371/journal.pone.0281933>



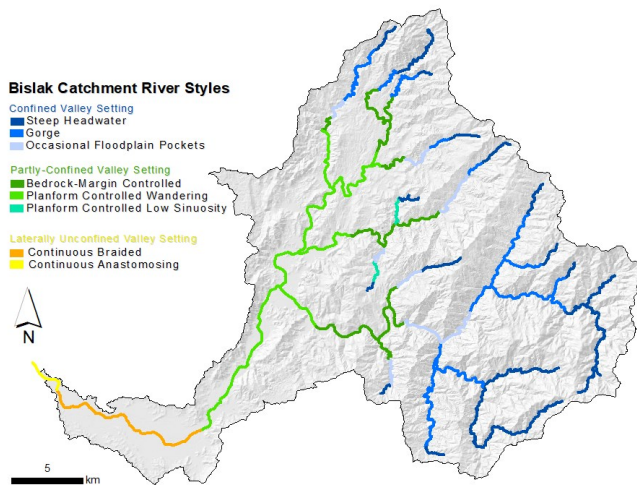


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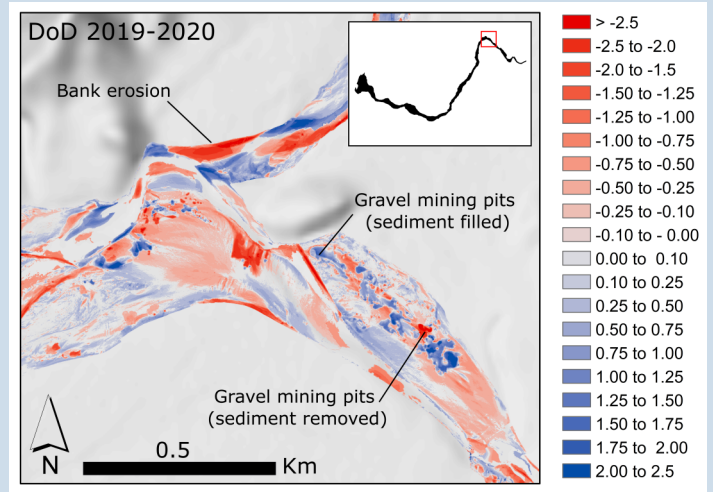
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Case study (2) Recognising the diversity of fluvial morphology within a catchment

Recognition of river diversity and understanding variation in river processes is essential for effective river management. In the Philippines, where water bodies are primarily classified based on water quality and quantity, the need to incorporate the integrated principles of geomorphology, hydrology and ecology has become critical. To demonstrate this approach, we used the River Styles Framework to classify river character and behaviour in the Bislak Catchment. We identified eight distinct River Styles. This revealed the diversity of reaches, which require different management strategies. Process linkages between these reaches (their connectivity) influence the evolution of the river. Knowing your river and its catchment is an important starting point to enable a move towards geomorphologically-informed, sustainable river management practices. Read the full paper here: <https://doi.org/10.1186/s40562-022-00211-4>

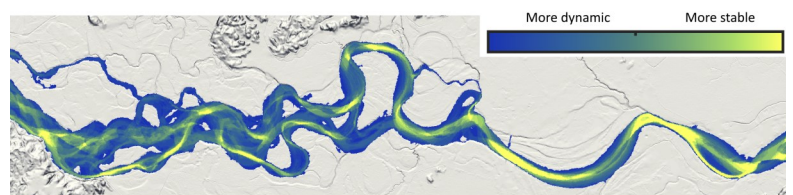


Case study (3) Identifying morphological river change



Repeat airborne LiDAR surveys from the Bislak River showed considerable morphological change between 2014, 2019 and 2020. Quantification of this topographic change to estimate a sediment budget showed that more sediment was eroded from the river than was deposited. Between 2019 and 2020, we estimated a sediment deficit of ~438,000 m³ with one quarter of the deficit attributed to gravel mining activities (103,000 m³). On average, the riverbed lowered by 0.03 m/year. Continuation of this rate over longer timescales could pose a threat to bridge foundations, dikes and embankments. The approach allowed us to identify the most sensitive parts of the river system, where morphological changes were highest. This information can guide proactive future sediment management plans.

Case study (4) Making space for shifting rivers



Different styles of river adjust in different ways over differing timescales. Some rivers in the Philippines are highly dynamic, with lateral migration rates of up to 30 m/year. This can be viewed as problematic where valuable land is eroded and infrastructure is damaged. Yet the same dynamism is crucial for maintaining healthy and resilient river systems. We mapped and measured the mobility of large rivers by analysing three decades of Landsat satellite imagery, to assess patterns of river mobility. Findings can inform future land use policies that makes space for shifting rivers by working with natural processes. Such practices could reduce erosion risk. Read the full paper here: <https://doi.org/10.1016/j.scitotenv.2020.144460>

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Policy implementation and recommendations

Based on the results of this project, we highlight a number of policy recommendations. If implemented, these recommendations could ultimately improve the lives of the Philippines' citizens through more effective water, river and flood risk management. They could also improve the ecological health of Philippine rivers.

1 Use the national-scale geospatial database of river and catchment characteristics for geomorphological, hydrological, water resource and natural hazard management applications.

Rationale: There are differences in the character, behaviour and evolutionary trajectory of river systems in the Philippines. Our free, open-access national-scale geospatial database provides baseline information for sustainable river management applications.

2 Use our example of repeat topographic surveys to assess river change to design and implement a monitoring strategy along rivers with sand and gravel quarrying.

Rationale: This project demonstrated how repeat airborne LiDAR can be used to quantify channel change from natural processes and sand/gravel quarrying. Regular topographic surveys (e.g. with drones, total stations, GNSS) could be used to license sustainable quarrying to avoid scour of structures (e.g. bridges, dikes) whilst meeting the needs of river ecosystems and flood risk management.

3 Use our Bislak River revised flood mapping study as a model to update flood hazard maps in river settings where there is considerable geomorphic change.

Rationale: Increases or decreases in sediment supply from natural events (e.g. earthquakes, volcanoes, landslides) or anthropogenic activities (e.g. bank protection) can cause river bed levels to change, altering a river's capacity to convey flood waters. Our research has shown how flood maps can be updated to provide communities with accurate information for decision making.

4 Use our river mobility database to review the measurement of legal easement zones and determine sustainable space for rivers to shift and flood.

Rationale: Legal easement is set to 3 m in urban areas, 20 m in agricultural lands and 40 m in forest lands. Our research shows how different styles of rivers require different amounts of space. Some rivers also have hotspots of channel mobility in particular places. Our findings can help inform erosion management measures that are sustainable and cost-effective in the long term.

5 Use our hydrological study to update methods to estimate discharge in ungauged rivers.

Rationale: We developed simple equations to estimate flood volumes based on catchment size and regional location. Combined with our national-scale geospatial database, practitioners can better understand flood magnitudes and how these are related to catchment properties. Due to climate change, planning needs to allow for possibly larger floods in future.

6 Use our example of applying the River Styles Framework in the Bislak River to embed fluvial geomorphology and a catchment-based approach to water, river basin and land use management.

Rationale: Our research has shown that Philippine rivers are diverse, typically dynamic, and respond to variations in sediment supply and anthropogenic change. Management decisions should incorporate a view of the river that extends both upstream and downstream, incorporating analysis of the whole catchment landscape and climate change impacts.