Research article

Systems Analysis and Modelling of Pollution Loading for Management of Calumpang River in Batangas City, Philippines

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Abstract The whole stretch of Calumpang River in Batangas province, Philippines is being considered for ecotourism development by the Batangas City government. Water quality of this river, however, falls under the Philippine Department of Environment and Natural Resources' (DENR's) classification as Class D – suitable only for agricultural and industrial purposes. Restoration to Class B is needed for the river to qualify for Recreational Water Use. This resource management concern needs to be addressed by the involved local government units (LGUs). Using systems analysis and modeling, a study on pollution loading of Calumpang River is conducted to generate information that will aid policymakers in crafting management options for the restoration. Factors, relationships, and processes involving people, land uses, and management practices that led to its current polluted state are identified and analyzed using the conceptual framework of the river system. Pollution contributions are identified and quantified. Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) are used in determining who should be responsible and accountable for the restoration and management of this water resource. Results showed that agricultural activities are the major contributor to the degradation of water quality in Calumpang River. Swine production, in particular, loads as much as 16,990 kg of solid waste daily. Using the physico-chemical and socio-economic characteristics and their pollution loading contribution as a basis in determining the degree of accountability, results showed that Batangas and Lipa cities have the highest level of accountability with an AHP value of 0.24, followed by Rosario (0.15), Ibaan (0.14), and San Jose (0.10). Establishment of a governing body as a management option can be recommended using the results of the study as a basis for determining the financial contribution of the accountable municipalities and the number of their representatives in the governing body.

Keywords systems analysis, Calumpang, watershed, swine, water degradation

INTRODUCTION

The Batangas City Government acknowledges the vital role of ecosystem services provided by the Calumpang Watershed, and the need for rehabilitation, protection, and conservation of the river to push forth its ecological tourism plan. This recognition led to the formulation of the Calumpang Watershed Rehabilitation and Conservation Strategic Development Program for 2013-2023 which is now in its third phase of implementation. Phase-1 focuses on socio-environmental preparations, education, information, communication (EIC), institutional mobilization and strengthening multi-stakeholder collaboration. Phase-2 focuses on watershed rehabilitation, resources, and technological investments. Phase-3 covers the feasibility analysis of river restoration and ecotourism hotspot development. This Phase requires cooperation and collaboration of all municipalities located within the watershed for though the Calumpang River is located within Batangas City, its tributaries cover six municipalities (Cuenca, Padre Garcia, Rosario, San Jose and Taysan) and two cities (Batangas City and Lipa City) (Fig. 1).

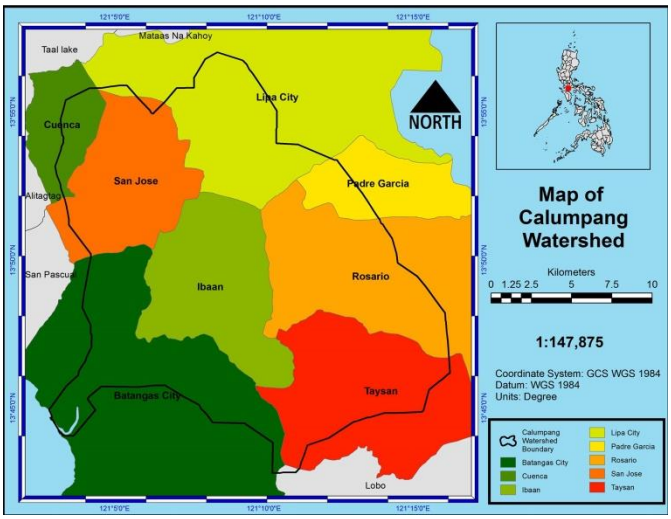

Fig. 1 Calumpang Watershed map

One major constraint in the proposed development is its water quality. In 2013, the group of Arboleda found the river to have high fecal coliform content (2 000- 130 000 MPN/100 mL), high level of Biological Oxygen Demand (BOD) (9-23 mg/L), and low level of Dissolved Oxygen (DO) (0.53-4.71 mg/L). In 2014, Cinco reported that Calumpang River was classified as Class D by the Philippine Department of Environment and Natural Resource (DENR), indicating that the water is not fit for any recreational activities and only fit for agricultural and industrial use. Identified potential cause of pollutants includes inflow of untreated domestic sewage and animal wastes from poultries and piggeries in the watershed. According to the Office of Provincial Planning and Development Coordinator, in 2010 there are approximately 870,000 people residing in the watershed, with only about 13.14% residing in Batangas City. Swine population is about 325,344 heads at any given time, mostly found in Lipa City (28.72%).

River rehabilitation and water quality restoration from Class D to Class B are challenges that the local government has to face as they pursue their plans for development. Batangas City can modify the polluting factors within their jurisdiction using physical, economic, and/or political approaches. However, since the watershed encompasses several municipalities and cities, baseline information as a basis for cooperative and collaborative river restoration is needed.

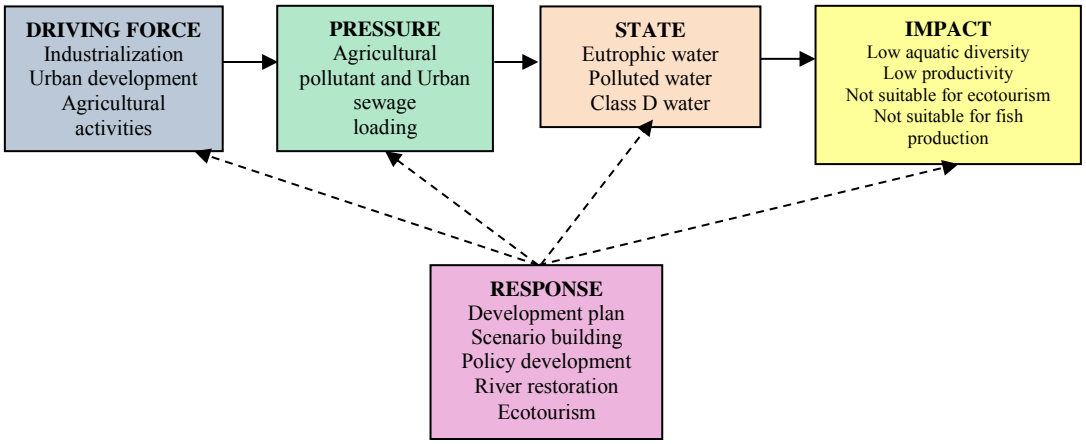

Fig. 2 DPSIR framework of Calumpang Watershed

Coming up uses Systems Analysis to study the Watershed and to pinpoint the heaviest contributor of pollution. This study can be used to justify that even though Calumpang River falls within the territorial jurisdiction of Batangas City, the restoration and management of the River can be made as a combined effort of all municipalities and cities in the Watershed. Fig. 2 summarizes the abovementioned discussion.

OBJECTIVES

This study aims to describe the effect of swine production and human population within the watershed to the pollution of Calumpang River; and to roughly quantify the extent of contribution of each municipality or city to serve as basis for restoration and rehabilitation accountability.

METHODOLOGY

This study was conducted from July to December 2014 as part of a commissioned project by the Local Government of Batangas City to the School of Environmental Science and Management of the University of the Philippines Los Baños. Primary and secondary data gathering was conducted in the area (Fig. 1) using the DPSIR framework shown in Fig. 2 as a guide for data requirement. System analysis approach was applied to analyze the state of Calumpang River system, the contributing factors to its current state, its impact to the people and environment, and the government responses to address the identified problems. Analysis was conducted using tools such as Geographic Information Systems (GIS), systems modelling and Analytical Hierarchy Process (AHP). GIS was used to generate information on loading process based on the amount of pollutants at source and proximity of pollutant sources to the river. The absence of data on the rate of flow of the tributaries is offset by estimating the amount and flow of water as affected by the soil, slope and elevation. This method was used to estimate the flow of pollutants from the source and the amount that reached the water. Lastly, a decision criterion, employing AHP, is set up to determine which municipality(ies) is/are accountable in the current state of the river and their level of participation that is crucial in the management and restoration of Calumpang River.

RESULTS AND DISCUSSION

System Analysis of Calumpang Watershed

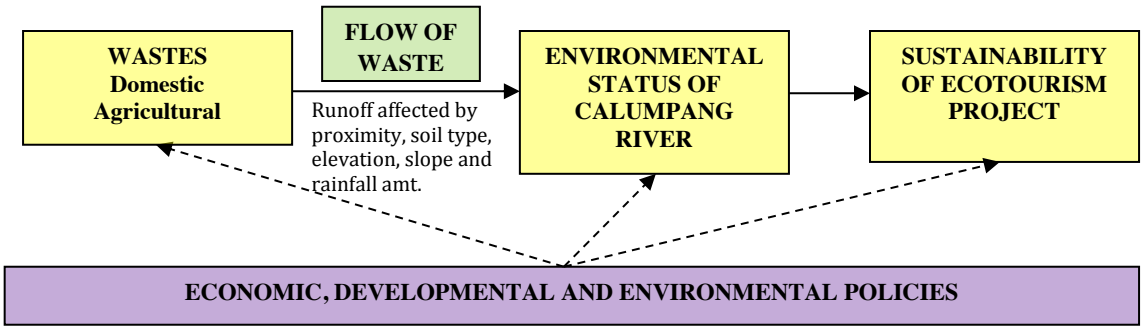

Fig. 3 Framework of Calumpang Watershed

Analysis of the Calumpang river system based from observations and data gathered in the area showed that though households typically have septic tanks or sanitation facilities, there are piggeries with no water treatment facilities and a few households with no septic tanks. The combined wastes of the residents and pigs from all municipalities will be received by a catchment point in Batangas City. The flow of water is not constant from each municipality; rate of flow is usually affected by elevation, slope, soil type, proximity to the area, and rainfall. The state of the water in the River will determine how successful the proposed ecotourism project will be. Initial analysis of the Calumpang river system shows that sustainability of ecotourism project is dependent on the environmental status of Calumpang River. The River is polluted due to the wastes coming from the different municipalities and cities within the Watershed which are using the tributaries as sink of domestic and agricultural waste (Fig. 3). To achieve a Class B, restoration of the River must be done. This can be done by introducing policies either at the waste source, such as reduction in number of pigs per farm; or at the River by dredging of the River; etc.

Computation of Total Wastes Received by Calumpang River

Using the above framework as a conceptual model of the Calumpang river system, quantification of the relationship was done. This can be used by policy makers as aid in crafting policies for the restoration and management of Calumpang River.

Table 1 Summary of parameters that affect the flow of water to Calumpang River

	Batangas City	Ibaan	Lipa City	Cuenca	Taysan	San jose	Rosario	Padre Garcia
Proximity (m)	0	5,851	16,511	12,745	10,965	9,051	12,099	18,187
Elevation (m)	1-100	21-500	101-500	201-975	51-500	101-500	51-200	101-200
Slope*	Flat to steep	Very steep	Flat to hilly	Domi-nantly hilly	Flat to hilly	Rolling to hilly	Flat to rolly	Flat to hilly
Soil Type	Hydrosol, Taal Sandy Loam, Calumpang Clay, Ibaan Loam, Ibaan Clay Loam	Ibaan Loam (Gravelly Phase), Ibaan Clay Loam, Guadalupe Clay Loam	Ibaan Loam, Ibaan Clay Loam, Lipa Loam	Ibaan Loam, Ibaan Loam (Gravelly Phase)	Ibaan Loam (Gravelly Phase), Guadalupe Clay Loam, Ibaan Clay Loam	Ibaan Loam, Ibaan Loam (Gravelly Phase)	Ibaan Clay Loam, Guadalupe Clay Loam	Lipa Loam, Guadalupe Clay Loam, Ibaan Clay Loam

**Flat= 0-3%, Rolling= 3-6%, Hilly= 6-15%, Steep= 15-30%, Very Steep= >30% measured near the river*

For the quantification, this study uses the value derived by Agbisit et. al. on swine daily waste generation which is at 0.26 kg, and the average daily human solid waste generation which is about 0.5 kg. Daily waste generation of each municipality and city were computed and the amounts of wastes that will end up in the Calumpang River were estimated. Due to lack of data on the amount of rainfall received per municipality or city, it is assumed that each municipality or city receives the same amount of rainfall per month or year. Also, only wastes produced by the residents and swine are included in the analysis since they are the highest waste generator. Table 1 summarizes the parameters that affect the flow of wastes to Calumpang River, while the summary of human and swine population can be found in Table 2.

Figure 4 shows the pollution loading of each municipality within the Calumpang Watershed. Results showed that Batangas City (7951.95 kg) is the greatest polluter of Calumpang River, followed by Ibaan (2707.74 kg), Lipa City (2204.94 kg) and San Jose (1583.25 kg). This result is expected since Batangas City is the nearest municipality to the catchment area, and the municipality that has the highest number of residents and second in number of swine. For the case of Lipa City, though this area is one of the farthest from the catchment point, its elevation, and its high number of residents and swine caused it to contribute more to the pollution. However, for Ibaan and San Jose, despite the low number of residents in the municipality, its proximity to the area, and the high number of swine caused the high amount in waste contribution. Meanwhile, Cuenca (1165.68 kg), Taysan (908.01 kg), Rosario (391.13 kg) and Padre Garcia (79.03 kg) are the least polluter of Calumpang River.

Calumpang River receives approximately 16,991 kg of wastes daily. If no intervention will be introduced in the area, the water will continue to be polluted: this may result to poor water quality in the region, which can then result to loss of biodiversity, loss of livelihood (fishery), illness such as diarrhea and other related diseases, the failure of the proposed ecotourism project, etc. This situation, if not solved, will make Batangas City's efforts to develop Calumpang River into an ecotourism site futile.

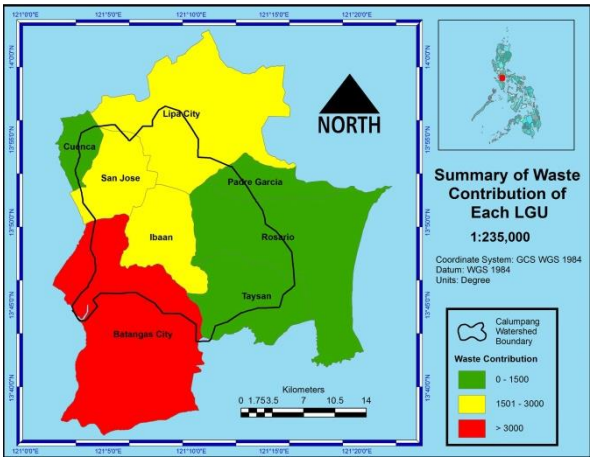

Fig 4. Summary of pollution loading of municipalities or cities in Calumpang Watershed

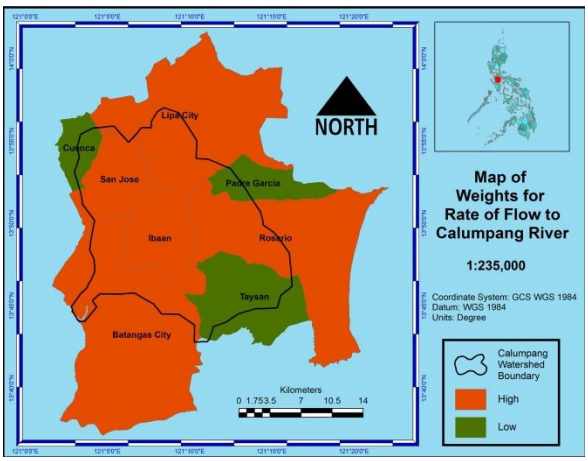

Fig 5. Summary of weights computed

Decision Criterion on Selection of Participants to Restoration and Management Project

Given that the river has many sources of pollutant which could exacerbate the declining water quality, the proposed ecotourism would not be successful. However, the problem is that Batangas City cannot be expected to clean up all wastes contributed by other municipalities and cities. If a governing body will be established to craft policies and implement restoration and rehabilitation program based on their

contribution and accountability in the water pollution, a basis for decision making is needed. For this purpose, AHP was used to determine which among the municipalities surrounding the River is more accountable and should be responsible for the restoration and management of the River.

Land area, population of residents, population of swine, and the area's contribution to pollution has been chosen as the criteria for joining this governing body. Land area is chosen since the larger the land area occupied, the higher its use of the Watershed. Population of residents and total swine units are chosen since the higher the number of these two factors will result to higher amount of taxes paid to the municipality or the city, which will result to the municipality or the city having more money to fund the project. Lastly, pollution loading is chosen since the higher this is, the higher the responsibility of the area to the pollution of the River.

Data used for these criteria are based on the study by Morales (2011). Table 2 summarizes the criteria together with the corresponding value per municipality. Note that the population of residents is taken in 2007, while the population of the swine is taken in 2011. Comparison of municipality or city is done pair-wise and the one that presents the higher value is given the higher point.

It has been found that Batangas City (0.24), Rosario (0.15), Ibaan (0.14), Lipa City (0.24), and San Jose (0.10) present the highest weights. Expectedly, these five municipalities are the ones with the largest land areas in the Watershed, the largest population, the most number of swine, and the greatest polluter of Calumpang Watershed. On the other hand, Padre Garcia (0.06), Taysan (0.09), and Cuenca (0.07) present the lowest weights.

Table 2 Criteria for joining the restoration and management project

	BATANGAS CITY	IBAAN	LIPA CITY	CUENCA	TAYSAN	SAN JOSE	ROSARIO	PADRE GARCIA
LAND AREA (ha)	6546	6881	5024	956	4971	5510	6550	893
RESIDENTS	295231	45649	260568	28581	33454	61307	95785	42942
SWINE	65498	34961	93452	2720	17722	28600	74410	7981
POLLUTION LOADING (kg)	7951	2708	2205	1165	908	1583	391	79

CONCLUSION

Calumpang River is predicted to be polluted, and the results show that every municipality contributes to it in different extents. Restoration and management program should be done to realize the proposed ecotourism project in Calumpang River. However, Batangas City government will need help from other municipalities and cities since each of them contributed in the pollution and, because of jurisdiction issues, Batangas City's restoration program cannot go beyond their administrative boundaries. Quantification of each municipality's contribution can be used as basis for determining the extent of accountability and responsibility in the restoration and management programs that will be introduced. An option to ensure rehabilitation and restoration of Calumpang River could be a creation of consortium or a governing body composed of municipalities contributing to river pollution. The members of such body must be proportionate to its contribution based on the results of this study. In terms of financial contribution or otherwise, further study should be conducted to determine its feasibility.

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Philippines Los Banos School of Environmental Science and Management (UPLB-SESAM). Maps were generated using the licensed version of ArcMap 9.2 of the SESAM.

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