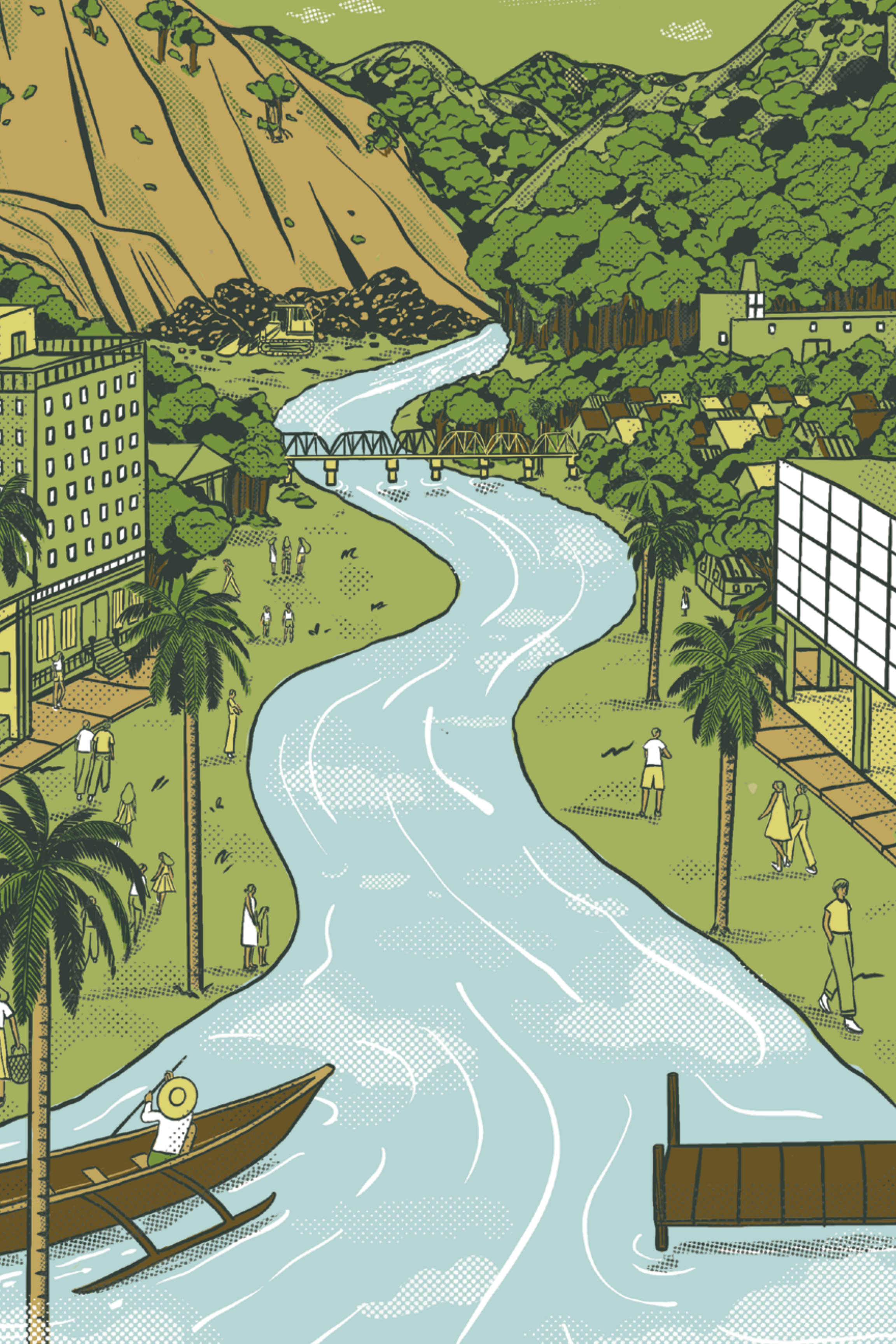


Examining Sustainability Issues in the Water-Dependent Economy of Downstream Sectors in the Cagayan de Oro River Basin

Catherine Roween C. Almaden, PhD

Abstract

Interrelated sustainability issues are examined in the case of the downstream water users in the Cagayan de Oro River Basin (CDORB), specifically Cagayan de Oro City (CDOC). The analysis focuses not only on technical or economic terms, but also in terms of political and social dynamics, the possibilities to meet the water needs of CDOC, and its linkages to forest conservation policy and programs. It describes water-dependent sectors and accounts for the economic benefits they derive from the CDORB. It also identifies potential technical and institutional options for supply and demand management and forest conservation to provide adequate water services for the various sectors. This chapter applies the systematic literature review method in which existing studies are aggregated, reviewed, and assessed. The main goal is to identify, critically appraise, and summarize the existing data about the CDORB and the water users in CDOC on the status of interrelated pressures to water management that pose sustainability issues needed for more holistic and responsive policy and regulation. The review and analysis on the sustainability issues of the various downstream users in CDORB provides insights on how competing demands for water are likely to play out in different settings. Cagayan de Oro City's water-dependent sectors rely on a number of ecosystem services that are critical for sustaining its growth and expansion, and the CDORB's ecosystem services are under serious threats that must be urgently attended to. There are also a number of challenges in dealing with transboundary water bodies governed by multiple agencies of the CDORB. In this Anthropocene epoch, the challenge lies on the increased capacity to regulate the actions of multiple users and determine how they can be changed to secure economic and sustainable development in the CDORB.

Background

River basin management has a strong tradition based on addressing environmental problems with technical solutions (Chen et al. 2005). Strategies in the planning and decision-making processes have started to evolve dramatically based on harmonious and environmentally sustainable ways and the inclusion of human dimensions (Almaden 2015; Rola, Pulhin, and Rosalie 2018). There is an increased emphasis on the accounting for social demands due to demographic pressures, changes in perspectives of the economic value of water, and climate change (Falkenmark, Wang-Erlandsson, and Rockström 2019).

The integrated approach to river basin management seeks to balance economic and demographic pressures, human water needs, environmental water needs, and a changing climate particularly in the context of the Anthropocene (Carr 2015). The onset of the Anthropocene poses challenges for forest management because of unprecedented changes in spatial distribution, structure, and composition. However, it also opens up opportunities for the creative management of forests to fulfil multiple values (Sun and Vose 2016). Increasing pressures on urban water resources incur added cost and highlights the inefficiencies of current water allocation regimes. Consequences of poorly functioning allocation include degraded environmental performance, lost opportunities for economic development, and unbalanced management of the risk of shortage (Brown, Dayal, and Rumbaitis Del Rio 2012; Molle and Berkoff 2009; Satterthwaite 2011).

Expanding urbanization entails increasing water demands for domestic, industrial, and commercial uses. These competing demands of burgeoning urban economy pose enormous sustainability challenges to the social, political, and physical environment of both upstream and downstream sectors of a watershed such as CDORB.

The main objective of this chapter is to examine the sustainability issues and water pressures from the downstream economic sectors in the Cagayan de Oro River Basin (CDORB), specifically Cagayan de Oro City (CDOC). It provides a purview of the ecological services derived from CDORB by the downstream water users and an integrated analysis on the technical, socioeconomic, and policy issues that influence sustainability and forest conservation. Intersectoral linkages, issues, challenges, and opportunities besetting the downstream economy are examined to provide insights on how competitions among water sectors play out in different scenarios. Potential technical inputs, institutional arrangements, and relevant policy for water management and forest conservation are identified. In conclusion, it outlines the implications of current water demand pressures of the CDOC downstream economy to policy development, the local forestry sector, and attainment of an integrated and sustainable river basin management.

Methodology

This chapter applies the systematic literature review method in which existing studies are aggregated, reviewed, and assessed. It aims to present a critical appraisal of the status of water-dependent economic sectors of CDOC, policy challenges, and sustainability issues besetting CDORB. Systematic literature reviews allow for the examination of coincident findings, as well as to identify themes that require further investigation. The method is particularly useful for the integration of information based on the objectives of the study and the selection of appropriate studies based on certain criteria (Aromataris and Riitano 2014). The bulk of secondary data on CDORB were sourced from the Department of Environment and Natural Resources Region 10 and the City Local Environment and Natural Resources Office (CLENRO) of Cagayan de Oro City. The data and information on water demand were gathered from the Cagayan de Oro City Water District (CDOWD). Secondary data related to the socioeconomic profile of CDOC were mainly obtained from the Philippine Statistics Authority (PSA). These secondary data were analyzed using descriptive statistics and trend analyses. Relevant findings from academic and research publications were also integrated in the discussion and analysis.

Basic spatial analysis was also employed through mapping of specific attributes of the water-dependent sectors covered in the study. This is intended to present patterns in characterizing the various sectors. The generation of analytical maps accompanying the tables and figures can potentially improve the analysis of a wide range of issues, letting policymakers, planners, and those who are not familiar with spatial analysis interact directly with relevant information (Lieske 2015; Zomer et al. 2008).

Brief Profile on CDORB and CDOC

The Cagayan de Oro River Basin (CDORB) is one of the major river basins in the country with an estimated length of 90 km and aggregate drainage area of 1,374.16 km^2. The river has its headwaters in the Kalatungan Mountain Range in the central region of Bukidnon province which joins those that come from the Mount Kitanglad Mountain Range, flows north, and picks up tributaries along the way as it traverses seven municipalities in three provinces, namely: Baungon, Talakag, and Libona in Bukidnon; Iligan City in Lanao del Norte; and Cagayan de Oro City in Misamis Oriental. The extensive networks of rivers and streams, which are located almost entirely in Bukidnon, converge into the main channel as water flows toward Misamis Oriental and finally drains into Macalajar Bay at its mouth in Cagayan de Oro City (Table 1, Figure 1).

TABLE 1. Areas of the various Local Government Units in the CDORB

LOCAL GOVERNMENT UNIT	AREA (HA)	%
Baungon	25,715	18.57
Libona	18,423	13.30
Talakag	63,596	45.91
Cagayan de Oro	10,856	7.83
Iligan City	12,079	8.72
Others, conflict areas	6,715	5.67
Total	137,384	100

Source: Data from CESM (2014)

Steep slopes are predominant in the upland area in the south and southeastern portion of the basin, where majority of the river's headwaters are located. They can also be found in the ridges of sub-basins where they serve as a topographic divide between sub-catchments. Gentler slopes and lower elevations prevail along the coast and on the flat portions of several elevated terraces around the basin.

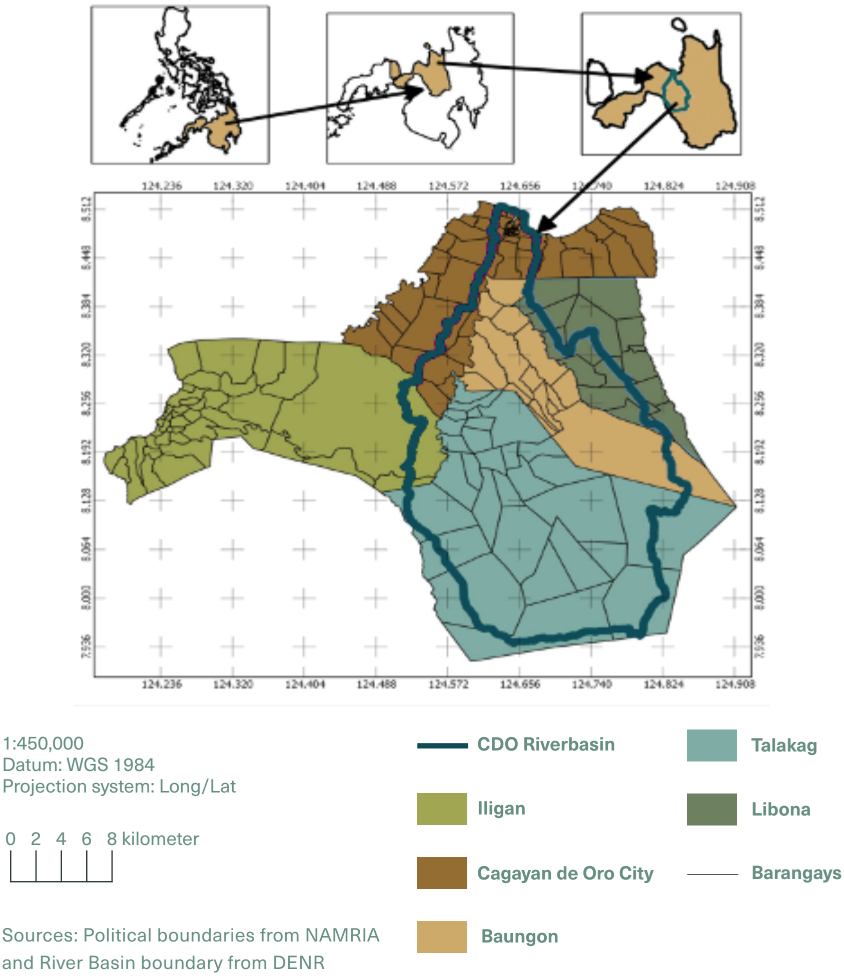


FIGURE 1. Location Map of CDORB

Cagayan de Oro City (Figure 2) is geographically situated between the central coastline of Macajalar Bay to the north and the naturally lush plateaus and mountains of Bukidnon and Lanao del Norte to the south. The municipality of Opol bounds the city on the west side while Tagoloan, with its heavy industrial activities, is its immediate neighbor to the east.

The city has a total land area of about 462 km^2. It is politically subdivided into 80 barangays, 57 of which are urbanized barangays and 23 are classified as rural barangays. These are grouped into two congressional districts: 24 barangays in the First District (West) and 56 barangays in the Second District (East), with Cagayan de Oro River as the natural boundary.

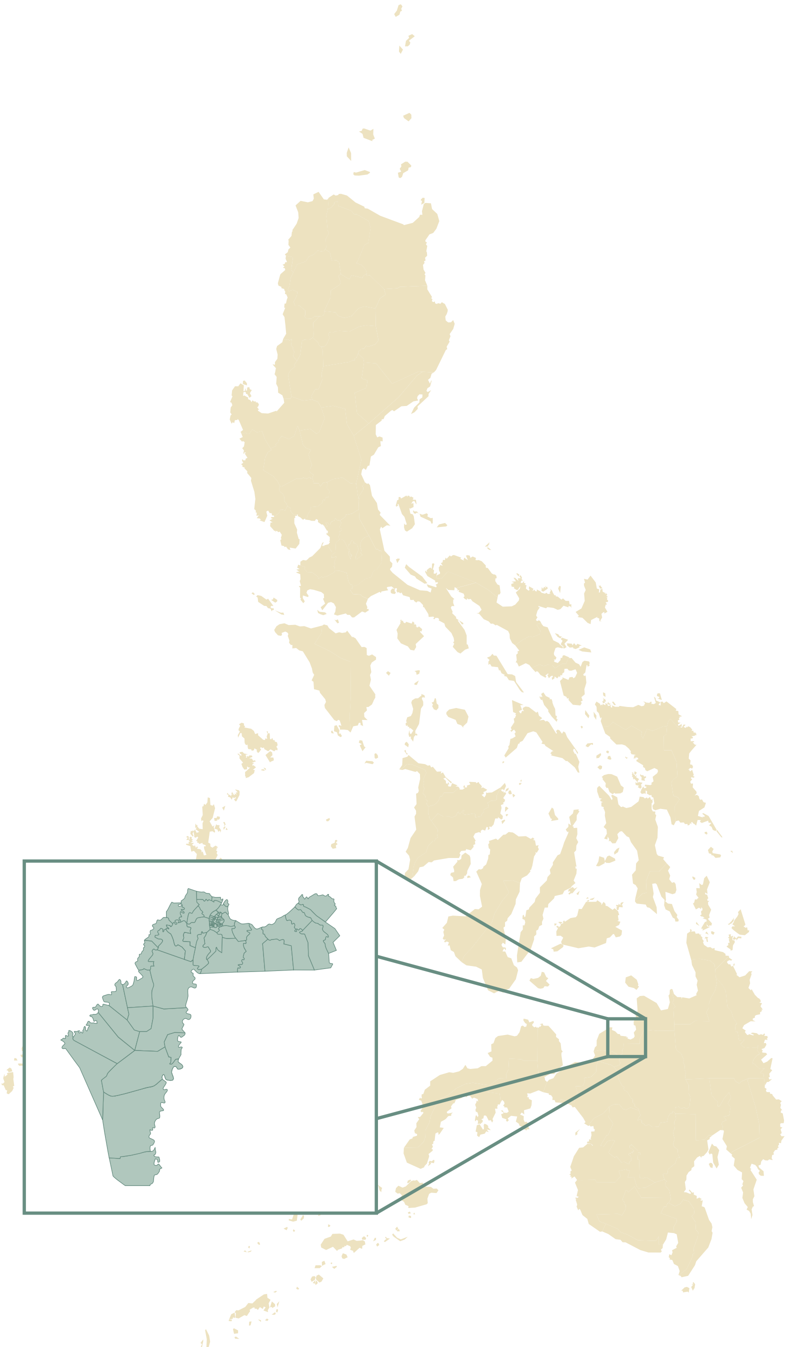


FIGURE 2. Location Map of Cagayan de Oro City

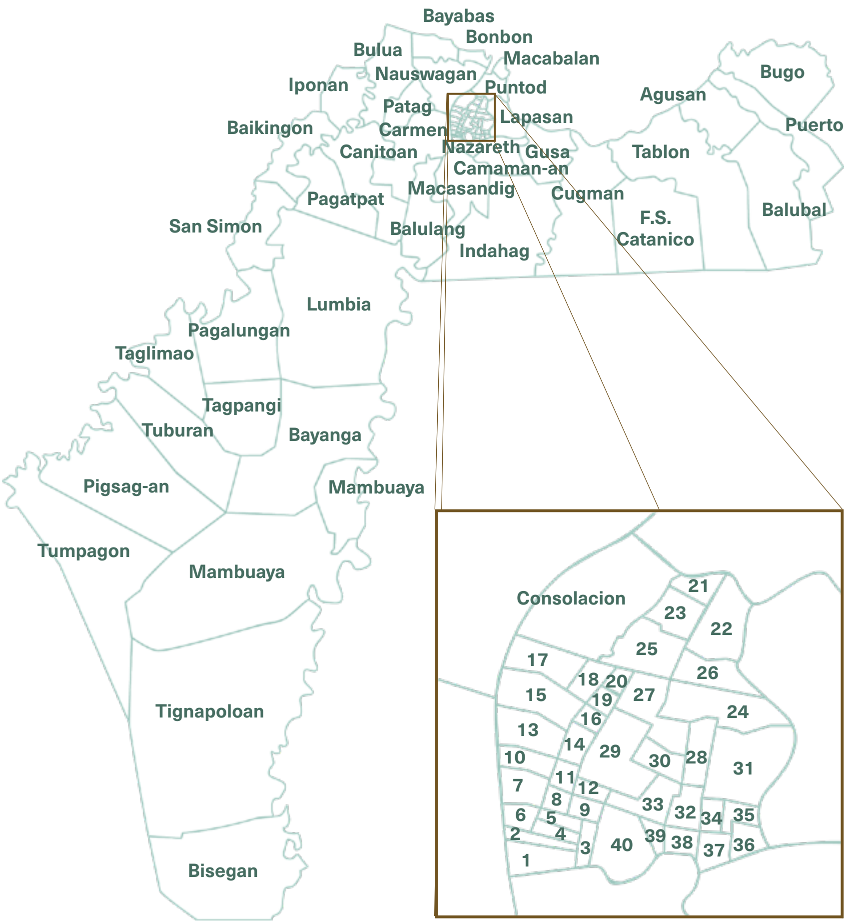


FIGURE 3. Location Map of Barangays of Cagayan de Oro City

Discussion

Urbanization Trends in Cagayan de Oro City

From 338/km^2 in 1975, population density almost tripled to 872/km^2 in 1995. Originally, the so-called Poblacion refers only to the urbanized section of the city. This is no longer the case, as 57 barangays have already been classified as urban in 1994. Urban zones encompass 40 Poblacion barangays and 17 adjoining urbanizing barangays. These account for 20 percent of the city's total land area and the concentration of 82 percent of its population at 3,519/km^2. The remaining 23 rural barangays have an average population density of 203/km^2 (Figure 4).

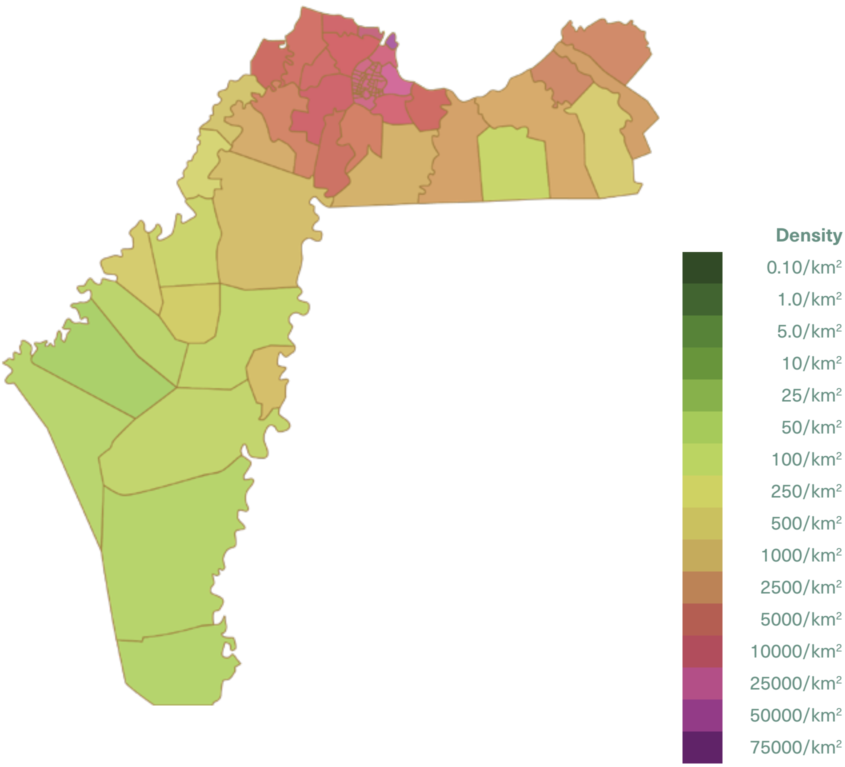


FIGURE 4. Population Density of Barangays in Cagayan de Oro City

Population growth is considered as one of the exogenous drivers of water use. As of May 2015, the total population of CDOC is at 675,950 and population density of the urban barangays has risen to 5,462/km^2. The 2015 figures translated to an annual population growth rate of 2.23 percent. The population represents the people who are located within CDORB and considered in the water demand projection. The total population in urban/urbanizing and rural barangays within the CDORB is estimated to increase from 572,283 in 2010 to 808,418 in 2030. Based on the present growth rate, the population will double in the span of 31 years or in 2046. As of 2015, the city has 683,793 in total household population with an average household size of 4.4.

The influx of people from nearby municipalities and current population growth rate of the city create pressure on job creation, among others. Labor force participation rate in the city is gradually rising at an annualized growth of 1.22 percent.

The large bulk of the city's income comes from the internal revenue allotment (IRA), constituting at least 75 percent. The rising local sources of revenue are due to the tax collected from businesses and property. The

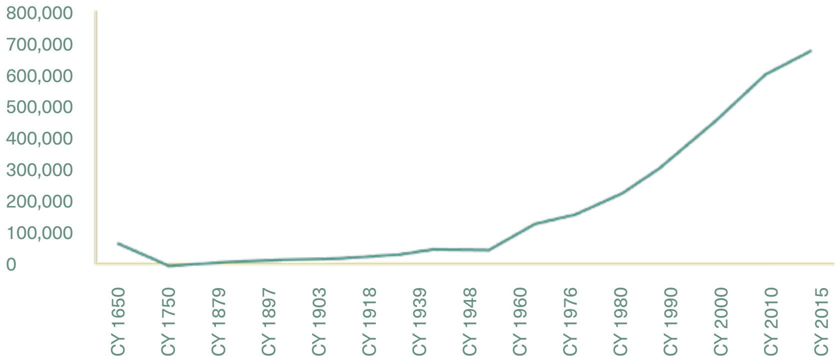


FIGURE 5. Actual Population Trend in Cagayan de Oro City

sprouting establishments covering the central business district, the recent expansion in the uptown area, and the rising number of landmarks and subdivisions are reasons of the appreciation of the value of land and increased collection of taxes (Almaden and Navarro 2018).

As the city grew, several nodes began to emerge. The Poblacion where main urban centers are located functions as the major node, while the southwestern part of the city, especially around Pueblo de Oro, is a new nodal point. Smaller nodes occur at the barangays Lapasan, Carmen, Bulua, and Puerto. The Poblacion and its contiguous areas comprise the present Central Business District (Figure 6).

Sustainability Issues in Water Dependent Sectors in Cagayan de Oro City

Urbanization Pressures

Increasing demand for water for domestic use

Use of water for domestic purposes is the utilization of water for drinking, washing, bathing, cooking or other household needs, home gardens, and watering of lawns or domestic animals. Per capita domestic water consumption varies considerably over the globe. In developed regions one can assume an average value of 200 liters per capita per day (l/c/d). The value adopted internationally for basic human water needs is about 50 l/c/d (Gleick and Palaniappan 2010). The Level 3 domestic per capita consumption for Cagayan de Oro City in 2010 is estimated at 180 l/c/d. By adding other types of consumption (commercial, industrial, institutional), other uses (irrigation, recreation), and unaccounted-for water (leakage, illegal connection, etc.), the total per capita consumption is estimated at 360 l/c/d,

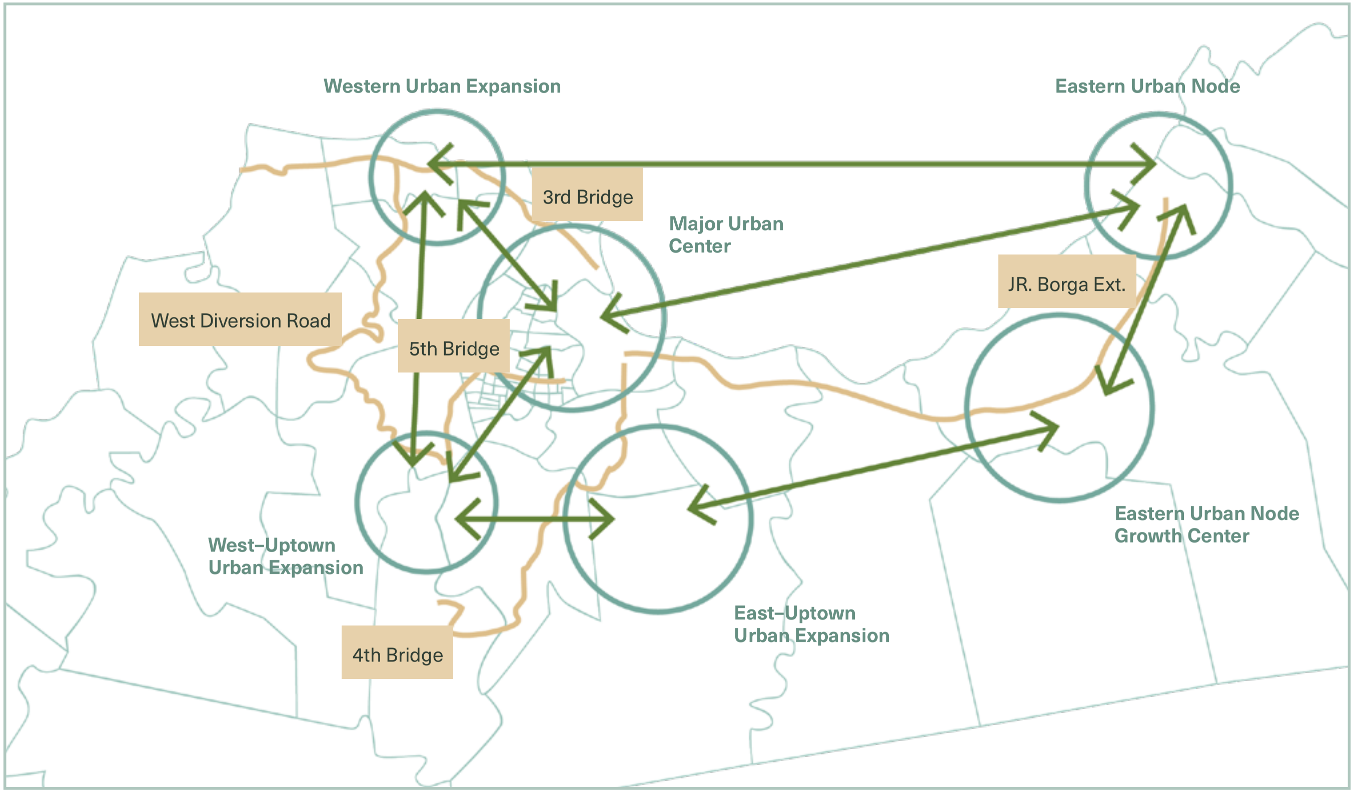


FIGURE 6. Cagayan de Oro City Urban Network Map. The circles represent major nodes/hubs for commercial and economic activities, while the arrows represent the flow of goods and services between the nodes/economic hubs.

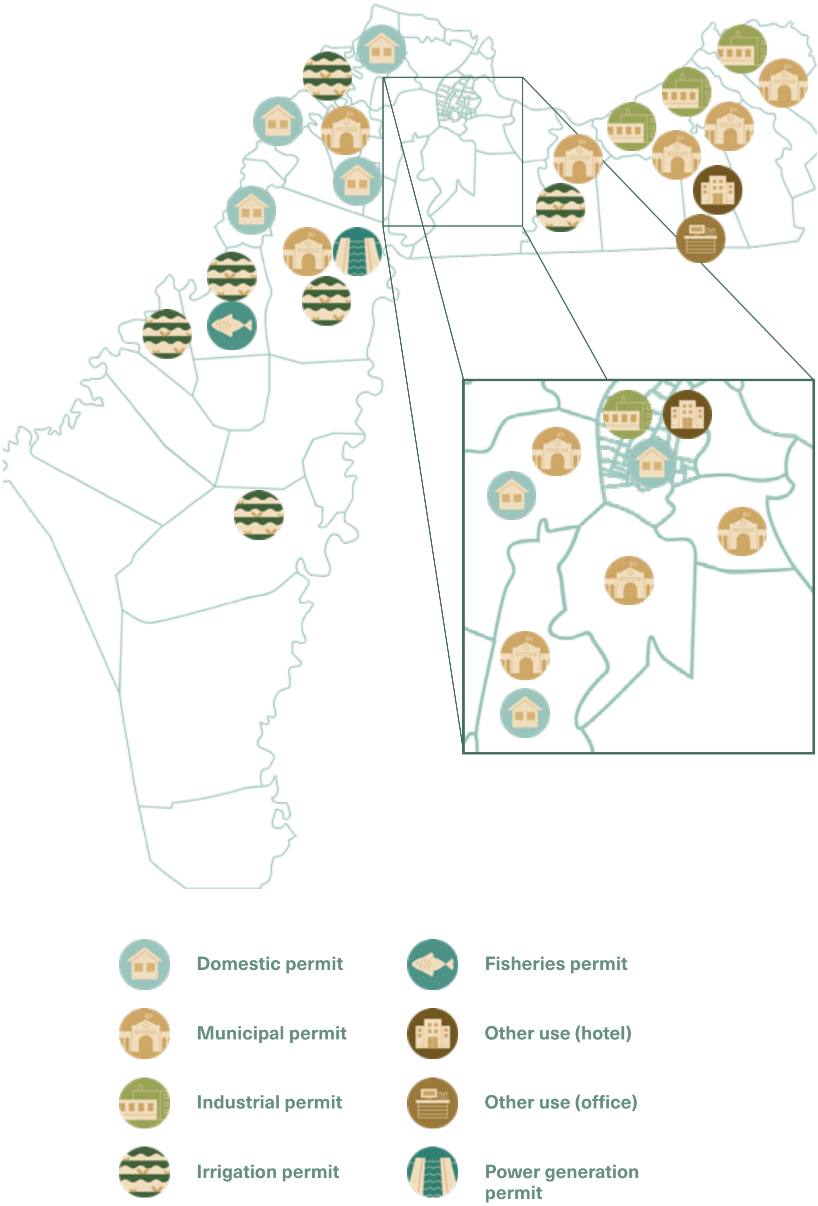


FIGURE 7. Permit types and classification per barangay in Cagayan de Oro City

BARANGAY	PERMIT GRANTEES: DOMESTIC	MUNICIPAL	INDUSTRIAL	IRRIGATION	FISHERIES
Agusan		2	3		
Baikingon	1				
Balulang	2	5			
Brgy. 24	2		1		
Bugo		5	7		
Bulua	6				
Camaman-an		1			
Canitoan	4	5			
Carmen	1	1			
Cugman		4		3	
Dansolihon				1	
Iponan				1	
Lumbia		3		1	
Macasandig		10			
Pagalungan				1	2
San Simon	1				
Tablon		2	8		
Taglimao				1	

which requires 142,607 m^3/d to satisfy the water demand of the served Level 3 population in 2010. The remaining population not served by Level 3 water supply utilized point sources or communal faucets or springs for their domestic use, which is estimated at 80 l/c/d. Adding other types of consumption (commercial, institutional) and other uses (irrigation, recreation), the total estimated per capita consumption for Level 1/Level 2 population is estimated at 120 l/c/d, assumed to increase at 1 percent per annum.

Other water utilities/companies present in CDOC cater to very specific groups/areas in the city, such as some areas in a barangay not easily reached by CDOWD water due to elevation or groups of subdivisions served by a water system developed by a real estate company. There is still a substantial proportion of households that rely mainly on public/community taps and public/community wells which provide free water. There are seventeen domestic permits approved by the National Water Resources Board (NWRB) in CDOC, most of which are classified as subdivisions and real estate developers that provide their own water system for residential use (Figure 7).

Based on the study conducted by Palanca-Tan in 2011, it can be deduced that there should have been an increase in domestic water permits given that demand in CDOC is growing due to continuing expansion and increase in the number of new subdivisions that cannot be serviced by CDOWD and have their own private construction of deep wells. The past decade witnessed the mushrooming of hotels, commercial complexes, and residential subdivisions in CDO, most of which put up their own deep-well systems. The study was able to generate a list of non-COWD deep wells which indicated the number of subdivisions, industries, and institutions (hospitals, schools) with their own deep well systems. Six subdivision developers and management companies are providing for the water requirements of 27 subdivisions through their own deep-well systems.

Table 2 presents the water demand projection from 2010 to 2030. From the estimated total consumption of 170,063 m^3/d in 2010, total consumption will increase to 331,187 m^3/d in year 2030.

TABLE 2. Groundwater Potential vs. Projected Water Demand

CONSUMPTION	2010	2015	2020	2025	2030
Total Estimated Consumption	170,236	203,337	241,474	284,081	331,187
GW Potential	539,427	539,427	539,427	539,427	539,427
GW Potential - Consumption	369,191	336,090	297,953	255,346	208,240
% of Consumption to GW Potential	31.6	37.7	44.8	52.7	61.4

Source: Data from CESM (2014)

With increasing population and number of households, it is expected that the residential areas in CDOC should reflect the economic importance of domestic water use in the area. Therefore, it is useful to see the geographical dispersion of the various settlement sites within CDOC. Correspondingly, a comparative study of the total number of households that have access to a network of water supply should be considered. The domestic water consumption must also reflect not only the aggregated size of water demand, but the demand across geographical scales.

Moreover, considering that population growth will focus in urban areas of CDOC in the coming years, this new demand will be added to the existing backlog of people still to be served. Currently, water shortage has been experienced in most barangays being serviced by the CDOWD and rationing has been implemented for several years now. There will be considerable difficulties in planning an infrastructure system that is adequate to future forecasts, and expandable as needed. To meet the need, ensure sustainable expansion, operate efficiently, and maintain a high quality of life for residents, CDOC will have to approach this problem using smart logic. Making CDOC a smart city would mean significant investment in water infrastructure must be appropriated.

With a growing population size and a greater freshwater demand, large volumes of wastewater are also generated, especially in densely populated areas. As a result, aquatic ecosystems may contain harmful constituents, including sewage (Brown, Dayal, and Rumbaitis Del Rio 2012). This a major concern in CDOC; it has no sewerage system and the existing rivers and creeks provide a natural drainage system. Most of the domestic sewage is dumped without treatment into the Cagayan de Oro river system. The primary sanitation facilities of residences, offices, and commercial establishments are septic tanks, which are unable to achieve the required pollution parameters required by DENR (Cities Development Initiative for Asia 2013).

Equity Issues Among Municipal, Industrial, and Commercial Users

Cagayan de Oro City continues to be the major hub of economic development activities in the Northern Mindanao region. In positioning itself as a preferred investment destination, the city consistently pursues its objectives along increased agricultural productivity, sustainable mining, manufacturing and construction activities, tourism revenues, and foreign and domestic investment.

In 2015, wholesale and retail trade continued to be the leading commercial activities in the city which accounted for 53.93 percent of total business establishments that year, with businesses engaged in community, social, and personal services trailing behind them at 14.36 percent (Figure 7). There are currently about 17,000 production-related businesses operating in CDOC with an approximate 1 percent rate of increase annually.

The city's top 30 manufacturing firms in 2015 reported total gross sales of PHP 20.923 billion, with manufacturers of essential items accounting for 74.3 percent (PHP 15.536 billion) of the gross sales and non-essential manufacturers at 25.7 percent (PHP 5.387 billion). The top 3 gross sales earners are engaged in food production (41.7 percent of total gross sales), non-essential manufacturing activities (25.7 percent), and agricultural manufacturers (19.2 percent). Collectively, these three firms accounted for 90.4 percent of the manufacturing sector's total gross sales during the said year.

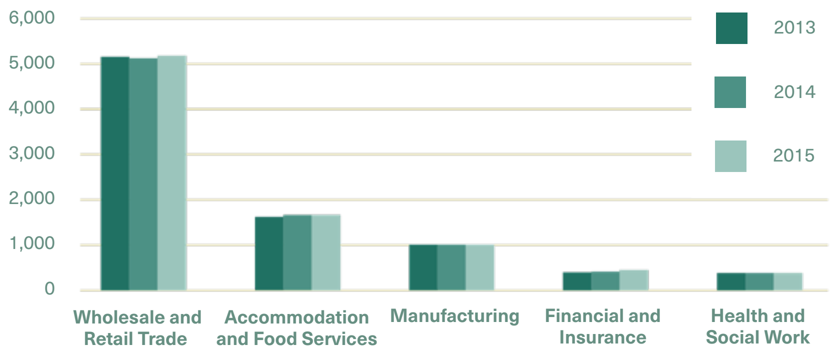


FIGURE 8. Business Establishments by Major Industry

Over the years, exports in Misamis Oriental relied largely on traditional products such as canned pineapple, sintered ore, crude coconut oil, finished lumber/wood products, activated carbon, fatty alcohols, refined glycerine, dessicated coconut, and coconut shell charcoal. The province's top 10 imports are minerals, hot rolled steel sheets, tin plates, chemicals, fertilizer, live animals, foodstuff, logs, carton making materials, and forest products. Majority of these commodities are used by industries in the manufacturing, repair, services, and agriculture sector. The major exporting countries are Brazil, Japan, Australia, Canada, and USA, among others.

As noted above, municipal and industrial water users are among the biggest number of users and abstractors of groundwater in the city. Use of water for municipal purposes is the utilization of water for supplying the water requirements of the community.

The increase in total municipal water demand in CDOC is driven mostly by the increase in urban population. In most emerging cities, there is also the tendency for economic development to increase the portion of the urban population that uses municipal supply rather than other sources, such as communal wells (Leigh and Lee 2019).

Cagayan de Oro is being served by a Level 3 system through the Cagayan de Oro Water District (CDOWD). The CDOWD is the first water district in the Philippines and was formed in August 1973, the same year that the country's Local Water Utilities Administration (LWUA) was established. To date, COWD's water supply system serves a population of 580,000, has a water supply capacity of 163,000m /day, and has a Non-Revenue Water (NRW) rate of 56 percent. The total length of COWD's distribution pipeline is 510 km, with about 54 percent of these PVC pipelines and 30 percent of these more than 30 years old. These factors are major causes of the high NRW rate. Thus, replacing the old and weak pipelines is essential for COWD to decrease the rate of NRW.

As of December 2019, the National Water Resources Board (NWRB) has granted 183 permits for tapping groundwater and surface water sources in Cagayan de Oro, Bukidnon, and Iligan City. Out of the 183 permits, 133 are granted to permittees located within CDORB, with 88 in Cagayan de Oro and 45 in Bukidnon. The two barangays in Iligan City which are covered by CDORB do not have any permits from NWRB. Majority of NWRB-permitted extractions within the basin are from groundwater sources for industrial and municipal consumption.

As shown in Table 3, a total of 1,285.30 lps or equivalent to 111,049. 59 m^3/d of water has been extracted from the groundwater reservoir daily by the 77 users for different purposes in CDOC. This represents an increase of 65.85 percent relative to 2012 data. In 2012, a total of 756.89 lps or equivalent to 65,395 m^3/d of water has been extracted from the groundwater reservoir daily by the 72 users for different purposes.

Like many countries in Asia, groundwater constitutes the primary resource for most cities and remains a valuable reserve water resource for countries that may have ample surface waters (Gleick and Palaniappan 2010; Helweg 2000). In the same manner, it is responsible for providing freshwater to coastal cities like CDOC. Rapid urban transition in CDOC is largely supported by the easy and adequate access to groundwater. However, benefits of groundwater use have come at the cost of resource depletion and degradation. In many cities in Asia, urbanization, population growth, industrial development, and the impacts of climate change are exerting huge pressure on groundwater resources (Grimaldi, Pellecchia, and Fasolino 2017). In Metro Manila for instance, resource sustainability is already threatened due to unwise development and use of groundwater and the increasing pollution.

Municipal consumption is highest at 713.54 lps or 61,649.856 m^3/d and represents 55.52 percent of the total daily groundwater extractions. Municipal use is mainly for Level 3 or piped water supply with a private water point from water districts and municipal water supply systems (ADB 2013). Municipal permits are concentrated in 10 urban barangays in the city (Figure 7). Industrial use represents the second biggest consumption of groundwater at 474.56 lps or 41,001.984 m^3/d, equivalent to 36.92 percent of the total. Industry used to be the biggest consumer of groundwater at 346.8 lps or 29,963 m^3/d, equivalent to 45.8

percent of the total in 2012. This may be attributed to the relocation of certain manufacturing firms outside the Cagayan de Oro City area.

Figure 7 shows that a significant portion of the Poblacion barangays of CDOC is host to four types of users: domestic, municipal, industrial, and commercial. Based these results we can see that an extensive portion of the territory may be unsuitable to host additional users or extensions of the water network. These same areas are also major sites of residential expansion, with the proliferation of high-rise condominiums in the city as well as the concentration of major malls and commercial buildings.

These areas have indirectly increased the costs of their transformation, as urbanization infrastructure-related expenses will be high. Data analysis,

TABLE 3. NWRB-Permitted Groundwater Extractions by User/Category, as of 2019

PURPOSE	CAGAYAN DE ORO		BUKIDNON		TOTAL		% OF TOTAL EXTRACTION
	# OF PERMITS	CAPACITY* LPS	# OF PERMITS	CAPACITY* LPS	# OF PERMITS	CAPACITY* LPS	
Power Generation	–	–	–	–	–	–	0.00%
Livestock	–	–	1	0.040	1	0.040	0.00%
Irrigation	1	10.000	1	13.390	2	23.390	1.80%
Domestic	17	84.930	–	–	17	84.930	6.54%
Industrial	19	474.560	–	–	19	474.560	36.54%
Fisheries	2	0.218	–	–	2	0.218	0.02%
Municipal	35	713.540	–	–	35	713.540	54.94%
Other Use	3	2.054	–	–	3	2.054	0.16%
TOTAL	77	1,285.302	2	13.430	79	1,298.732	

* Volume of extraction granted by NWRB
Source: Data from NWRB (2019)

then, should incorporate the choices to be made in the city plan regarding the placement of additional demand of services. On one hand, allowing more economic activities in the area will only result in increasing investment costs if the concept of densification of services and buildings are not considered (Li 2013; Stoker et al. 2019). Nonetheless, utility providers usually support this scheme since in highly urbanized and dense areas with high service coverage, it is possible to serve more users with lower implementation and management costs. Conversely, in slightly urbanized and scattered areas with low service coverage, it takes several meters of network to serve a few users, which results in very high costs of implementation and management. The logic of densification become a major consideration in the attainment of economy and efficiency (Grimaldi et al. 2017). With this, the suitability of additional investments in the areas for expanding productive activities must also consider the suitability for water service networks.

Apart from increasing water demand, another problem currently faced by the CDOWD is significant water losses in the distribution network, also known as non-revenue water (NRW), which can reach as high as 54 percent of the volume introduced. This is commonly due to the poor condition of water pipes and obsolete infrastructure. NRW also usually goes up when there are road and building construction projects, as well as losses due to pilferage; leakages in pipes, joints, and fittings; pipe repairs; and reservoir overflows. This was also exacerbated by budgetary constraints and government red tape since CDOWD was reverted to government control (JICA 2014). This points to an equally critical issue in water resource management in the city: inefficiency. The current status of groundwater depletion in Cagayan de Oro may be controlled to a substantial extent by addressing inefficiencies in CDOWD's operations.

The problems with leakage are not only related to the efficiency of the network, but also to water quality (contamination of drinking water if the pressure in the distribution network is very low). Leakage reduction applies to both distribution and customer supply networks (Stoker et al. 2019).

The growth and geographical shifts of population in CDOC has entailed an increase in built-up areas and changes in commercial and industrial land uses. Data on land use changes from the City Assessment Department revealed that residential and commercial areas almost doubled, reflecting the urbanization process, while industrial lands grew more than tenfold from the last twenty years.

Figure 7 shows there are nineteen industrial permit grantees in four barangays. These barangays are found in the eastern side of the city where most manufacturing firms agglomerate. Surprisingly, this data for 2019 is much lower than the data in the 2011 study of Palanca-Tan wherein 46 deep wells were identified to be owned by both industrial and commercial companies.

Plans for expansion in the industrial zone of CDOC are likely now that the demand for industrial water use will increase, considering the need for new land for the establishment of industrial units (Table 4). Industrial water supply is estimated to have an increasing trend if the relevant city government plans are realized. If so, the competent bodies for providing water services in CDOC will be of particular interest. As a response, water provision and treatment as well as water abstraction points must be diversified across the competent bodies, so that different quality, quantity, and charges for water must be observed.

TABLE 4. Projected Water Demand per Sector

UNIT: M³/CAPITA/DAY	2010	2015	2020	2025	2030
Municipal*	88,318	104,460	123,782	145,339	169,143
Commercial/Industrial/ Institutional	24,879	31,338	37,135	43,602	50,743
Other Uses	17,614	20,889	24,756	29,068	33,829
Unaccounted for Water**	39,425	46,650	55,801	66,072	77,472
Total	170,236	203,337	241,474	284,081	331,187

Note: Percentage of population served for Baungon, Talakag, and Libona is taken from their respective Comprehensive Land Use Plan (CLUP)
*Municipal Consumption is composed of Level 1&2 and Level 3 water supply
** Unaccounted for water is due to leakage, illegal connection, etc.

Determinants of industrial water use and return vary from industry to industry as they are influenced by the technology employed (McGrane 2016). In CDOC, there is a current shift of productive activities concentrating on commerce and trade. A growing concern in the city is not only water provisioning for the increasing water demand from these sectors, but also the effluents as byproducts of water use from these sectors. Sewerage and water treatment facilities remain almost nonexistent, and stringent standards or regulations governing the quality of discharge waters have not been intensified to encourage recycling of industrial and commercial water, which would allow for significant reductions in total water used as well as a reduction in the quantity of wastewater discharged. Commercial and public uses of wastewater are currently not well studied and understood. Again, a more complete picture could be obtained by also checking the effects of droughts on the use of water in these sectors.

For industries that recycle water, the cost of recycling a unit of water could also be estimated. All these methods reflect the upper bound that industry sets on the value of water (Joachim et al. 2015).

Exacerbation of Sustainability Issues with Climate Extremes

Agriculture

The availability of water is a key factor for the development of agriculture, as well as a requirement in satisfying the increasing needs of the population as standards of living improve (Strzepek and Boehlert 2010). In the case of the CDORB, it performs a dual function in providing livelihood to upland farmers in CDO and in preserving the agricultural resource base. The upland area surrounding CDO is critical in maintaining the ecological balance of the city. It provides the necessary watershed that ensures steady flow of water supply, prevents siltation of the river system, and minimizes occurrence of floods. It also supports agriculture that can produce food needs of farming households while enhancing fertility of the soil.

In 2015, agriculture accounted for the use of 32.4 percent (18,744 ha) of the city's land area (57,851 ha). The agricultural areas of CDO are located mostly in the rural barangays, although patches of productive agricultural lands are still found in the lowland barangays, some of which already belong to the urban classification. Existing agricultural areas of the city totaled 16,393.39 ha.

The city's agricultural land, comprising about 53.4 percent, is dominantly used for crop production that includes rice, corn, vegetables, and various commercial crops (Table 5). Areas devoted for coffee, cacao, fruits, and nuts have significantly increased in recent years.

TABLE 5. Area of Crops Harvested in Cagayan de Oro City

CROPS	AREA OF CROPS HARVESTED (IN HECTARES)		
	2010	2016	% CHANGE
Corn	2,848	2586.5	-9.18
Rice	104	77	-25.96
Vegetables	587.5	295.9	-49.63
Banana	1,225.5	866.8	-29.27
Rootcrops	931	990	6.34
Coffee & Cacao	52.5	100	90.48
Fruits & Nuts	846.5	13,789	1,528.94
Abacá	14	31.5	125.00

TABLE 5 (CONT'D)

Coconut	50.4	2,862	5,578.57
TOTAL	6,659.40	21,598.70	224.33

Source: Data from Cagayan de Oro City Agriculture Office (2017)

The current NWRB data shows an increase in total number of permits granted for irrigation from surface water, from only two in 2012 to eight in 2019 (Figure 7). It can be attributed to the increase in production areas for coffee, cacao, and fruit trees based on the latest data for 2019. Seven of the permits are for surface water extraction and only one permit is sourced from groundwater. All of these permits are intended for irrigation purposes for crop production. Four permits are located in four rural barangays while another four are two urban barangays.

Where water demand for agriculture is increasing, irrigation typically takes over (Dziegielewski 2003). This might be the case in CDOC. The city faces the challenge to reliably produce more supplies and more varieties of food. As a result, higher pressures on water for food production may be expected to develop because large segments of the population in the city will tend to raise their standards of living. Consequently, increasing urbanization will impact the volume and quality of water available for agriculture, particularly in peri-urban areas. Increasing demand for water in cities, industries, and for environmental flows will reduce the volume of water available for agriculture.

Just like other sectors, the threat of droughts can have serious negative impacts on the water quality needed for irrigated agriculture. The most recent episodes of drought have adversely affected many farmers in the rural barangays in the city.

The case of the Higaonon community in Dansolihon, an upland barangay in Cagayan de Oro, presents a case of a vulnerable farming system where a narrow focus on productivity may not be sustainable. Most of the Higaonon people cultivate logged-over timberland, which is technically owned by the government. With high elevation and sloping terrain, soil is easily eroded, causing siltation of the rivers. As a way of addressing this problem, the national government launched the strategy of Community-Based Forest Management (CBFM) where the communities are tapped to rehabilitate, protect, and conserve the forests by granting them the management and sustainable use of the remaining forest resources. To formalize this arrangement, the forest occupants are given a certificate of stewardship contract (CSC) for individual farmers or families, a Community-Based Forest Management Agreement (CBFMA) for the entire community, and/or a Certificate of Ancestral Domain Claim (CADC) for organized indigenous communities. With the awarding of this tenurial instrument, the farmers have secured their place in the community, opened access to other services such as credit, and started to make long term plans in increasing agricultural productivity and in conserving the resource base (Ravanera 2001).

Fishery

CDOC is a coastal city, and for this reason, a good number of families still depend on fishing as their major source of income. Coral reefs are found along the coastline of eleven barangays along the Macajalar Bay. In addition, inland artisanal fishing is also practiced in several communities in CDOC, mostly those found along the river areas. The author's research in 2015 estimated that the total population of fishing communities in the city was less than 5 percent of the total population, and that there are only two fishery permittees in CDOC in the 2019 record of NWRB. These are found in the rural barangays in the hinterland section of the city (Figure 7).

A study of the author in 2015 analyzed artisanal fishery in the CDORB. Artisanal fishing is an important socioeconomic aspect of the communities in the CDORB, but has remained undocumented by Local Government Units (LGUs) as it does not contribute directly to the economy in terms of measurable cash flow. Very little was known of the scope and magnitude of artisanal level fishing activities within the CDORB, as it is an ancillary livelihood in most of the areas. Most fisherfolk have subsidiary occupations which serve the dual purpose of alternative income and job opportunities, as well as food source, since fishing is seasonal (the peak fishing season usually spans two to four months). In rural communities of CDORB, most fisherfolk resort to farming as their subsidiary occupation at the onset of the rainy season during which fish catch tends to be lower (Almaden 2017).

There are 26 commonly identified varieties of fish in fishing communities in CDOC. Each area tends to have a different concentration of fish variety. The concentration of fish in each zone tends to vary according to season. *Pigok*, considered as the second most expensive freshwater fish in the Philippines with prices that can go as high as PHP 1,200 per kilo, is considered endemic in CDORB and dominant in most of the downstream and midstream communities, while *carpa* is most abundant in the upstream communities.

The artisanal fishery sector in CDORB has the following elements that can be called almost general characteristics to artisanal or small-scale fisheries (Clifton and Foale 2017): 1) it uses relatively simple technology, 2) it is labor intensive, 3) it consists of small groups of operators, 4) it takes relatively low capital inputs, 5) its marketing and distribution are handled by specialized non-fishing intermediaries, and 6) its risk-aspect is always present. Fishing is a low-status occupation and fishing communities suffer from poor community infrastructure and living conditions. On average, fisherfolk spend around PHP 3,000 pesos a year on equipment.

The peak and lean seasons vary for all zones, and even among communities within the same zone. The peak season in downstream communities tends to coincide with the rainy season. According to fisherfolk in the area, this may be attributed to flooding which increases the likelihood of fish from the upstream river sections to be carried downstream. On the other hand, for most of the midstream and upstream communities, peak season coincides with the dry season because more fishing activities can be conducted when river water is more manageable. Also, the fishermen are able to dive into deeper channels of the river where potential fish catch is higher with tamer water current. During the rainy season, full-time fisherfolk resort to the use of *besigan* or river traps to ensure continuous fish catch despite harsh river conditions.

The downstream area recorded an average weekly fish catch of only 5–10 kgs of mainly smaller immature fishes. This fishing output suggests that this portion of the river has already been heavily fished. In the midstream communities, average fish catch is almost the same as the downstream, suggesting a similar situation. In the upstream communities, however, the average fish catch is between 10–15 kgs a week, suggesting relative abundance. In most instances, full-time fisherfolk's number of fishing trips per week ranges from four to six. This high fishing frequency is an indication of heavy dependence on fishing as a means of livelihood. During the lean months, fish catch tends to be lower by 40 percent for most of the fishing communities.

Fish prices range as low as PHP 50 and as high as PHP 400 at the fisherfolk's level. Usually, the fish vendor's price is higher by PHP 20–100, depending on variety. Because of the relative scarcity of most of the fishes, prices do not vary much during peak and lean seasons. The fish prices also differ by zone; in rural areas, most of the fishes are cheaper by PHP 20–100. According to the fishermen, the top three most expensive fishes are damagan, pigok, and balanak.

The net value analysis of fish caught in the study area has shown that artisanal fishery generates significantly high net values. These figures are presented in Table 6 below. The table shows that these high net values can be attributed to the relatively low expenditures incurred by fisherfolk in the various areas. Overall, the fishing sector in selected communities along the CDORB generates a total net value estimated at PHP 59 million annually.

The intimate connection between watershed and inland fisheries was also highly valued in terms of the nutritional security and income to hundreds of millions of rural households (Almaden 2017; Clifton and Foale 2017; Nguyen et al. 2016; Welcomme et al. 2010). Although commercially intensive fisheries exist, inland fisheries are generally characterized by small-scale/household-based activities. Participation in fisheries is high and the bulk of the catch is consumed locally. By-catch is insignificant as practically all fish caught are used. This means that their benefits are widely spread. Inland fisheries are also very diverse, being based on a range of ecosystems (Lynch et al. 2016).

Through the years, activities in the upstream communities of the CDORB have adversely affected the fishery sector. The dissertation of Mars P. Tan (2017) studied extensively the sedimentation dynamics of the Cagayan de Oro river and its implications for its catchment in the coastal marine environments of the Macajalar Bay. The study noted the relationship between rain and run-off, which is influenced by a site's spatial variation over time such as rapid increase in the human population, along with an expansion of land-based activities, particularly large-scale land cultivation, mining activities, timber poaching, quarrying, and logging. Despite the frequent extreme rain events such as the three recent typhoons Sendong (Washi) in 16 December 2011, Pablo (Bopha) in 12 December 2012, and Yolanda (Haiyan) in 8 November 2013, the Cagayan de Oro River catchment remained largely stable, but possesses a small number of erosion-prone sub-catchments, which have a high potential to cause massive floods of water and mud during extreme rainfall events. In extreme discharge events with high-sediment volumes, sedimentation poses a direct threat to both corals and seagrass communities, but not to mangroves.

Nonetheless, river sedimentation has brought benefits to the coastal environment due to the accretion and expansion of landmasses, and later the subsequent colonization of mangrove trees. However, it has also paved the way for major physical modifications to the coast and riverbank, facilitated by human intervention at the expense of naturally growing mangroves. The distribution and abundance of mangroves, corals, and seagrasses within the Cagayan de Oro River coastal environment indicated their response to the sedimentation dynamics. The study acknowledged the need to conduct management interventions at different points along the ridge-river-reef continuum where sedimentation has become anomalous.

Quarrying of sand and gravel

Quarrying is an important sector in the Philippines in support of the country's infrastructure and overall economic development. The most important products of this activity are rock aggregates, colloquially known as sand and gravel. They form a significant 39.33 percent of the non-metallic mineral output and 14.49 percent of total mineral production in the country. In addition, the shares of sand and gravel output to nonmetallic mineral and total mineral production generally have been increasing, further manifesting the importance of quarrying to the mining industry (Israel 2001).

Sand and gravel are used intensively in the construction industry, in chemicals and metals processing, and in plastic industry. These multiple utilizations led to an exponential consumption growth and this trend is expected to continue due to population growth and increasing standards of living. The importance of this natural resource is given by the fact that, nowadays, after fresh water, sand is considered to be the second most consumed natural resource on Earth (Dan Gavriletea 2017). Despite this, their use greatly exceeds their natural renewal rates (UNEP 2014).

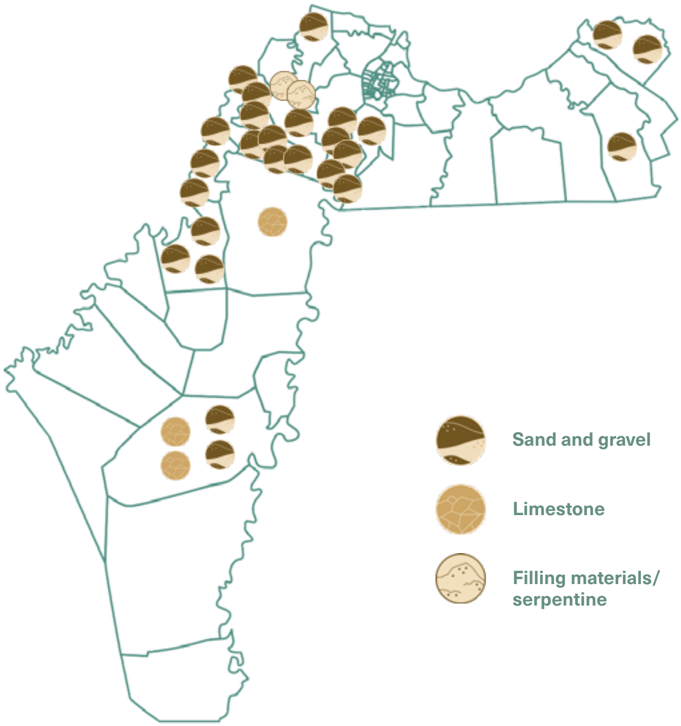
Cagayan de Oro City's infrastructure needs have been supported substantially by quarrying of sand and gravel sourced from the Cagayan de Oro River (CDOR) and the Iponan River. These rivers and floodplains have also become the major sources of sand and gravel for the construction boom in the city. Thirty-three companies in CDOC were granted quarrying permits by the Mines and Geosciences Bureau (MGB) as shown in Figure 9. Twenty-six of the grantees were given permits to quarry sand and gravel along the CDOR and twelve along the Iponan River.

Quarrying and dredging for sand and gravel are contentious issues. While quarrying is important for economic growth, it is also a major natural resource-extractive sector that causes significant environmental problems. The extraction of sand and gravel from the rivers, streams, floodplains, and channels conflict with the functionality of riverine ecosystems (Israel 2001). Some of the disturbance is from the mining methods and machineries used. The most common environmental impact is the alteration of land use, most likely from underdeveloped or natural land to excavations in the ground (Cristóvão et al. 2012; Dan Gavriletea 2017; UNEP 2014).

Siltation results in shallower rivers; shallow waters easily overflow. In the aftermath of Sendong (Washi) in 2011, experts had blamed shallowing and constriction in certain parts of the CDOR due to siltation and accretion. Both are results of loose earth going into the waterway which accumulated over time. Before Sendong, the MGB marked the downstream areas along the CDOR as flood hazard areas and recommended these areas “no-build zones.” They also recommended for the removal of the silt and sand through quarrying. For the construction industry, removing these massive appendices of the river bank is a very good business proposition as these would become an abundant source of affordable filling materials and concrete aggregates.

Water pollution

With the increasing demand for water, wastewater also increases. A 2019 report of the Monitoring and Enforcement Division of the Environmental Management Bureau (EMB) of Region 10 noted that the CDOR receives some 12,000 m^3/day of domestic wastewater from inhabitants in barangays along the CDORB. Domestic wastewater combined with rain runoff flows is collected in ditches, flows in discharge points, and then goes untreated into the river. The absence of a sewerage system in Cagayan de Oro City is among the factors attributed to high levels of fecal coliform contamination of the river, which can be traced up to its drainage in the seawater of barangay Bonbon. It was reported that fecal coliform reached 248 most probable number (MPN) per 100 mL, higher than the 100 MPN/100 mL standard. The results have serious implications to the functions of the river system for the downstream communities of the city.



	PRODUCED QUARRY		
BARANGAY	SAND AND GRAVEL	LIME	FILLING MATERIALS
Balubal	1		
Balulang	5		
Bugo	2		
Bulua	1		
Canitoan	1		2
Dansolihon	2	2	
Lumbia			1
Macasandig	1		
Pagalungan	3		
Pagatpat	7		
San Simon	3		

FIGURE 9. Quarrying Permit Grantees by MGB in Cagayan de Oro City

The EMB of Region 10 carried out water quality testing of the CDOR at four different locations in Cagayan de Oro City and the Bubunawan River in Pualas, Bukidnon on May 2019. Water quality analysis from 100 different groundwater sources, which include deep and shallow wells, dug wells, and free flowing wells was conducted to check if the water meet the National Standards for Drinking Water (NSDW) limit. Out of the 100 tested samples, 21, 40, and 28 exceeded the limits in Total Dissolved Solids (TDS), conductivity, and hardness, respectively.

As for surface water, under the DENR System of water classification, CDORB rivers were identified as “CLASS A,” in which treatment is required to meet the NSDW. Test results for different water quality parameters indicates that CDOR and Bubunawan River still meet the required standards for Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS) and pH. A 3°C increase in temperature was recorded from the sampled and tested waters, but still within the allowable limits, while turbidity is reported to be NS or not significant. However, very high fecal coliform values were found in the sampled water, indicating serious contamination. Most contaminated water was found in areas at Pelaez Bridge and Carmen Bridge. Fecal contamination may be attributed to animal manure disposal into the river from households with domestic animals and livestock, some households that have comfort rooms draining directly to the river, and informal settlers who improperly dispose human waste into the river.

The quality of available water in the CDORB diminishes with the wastewater. Municipal wastewater or sewage contains organic compounds and solids that have to be removed through sewage treatment (Loomis et al. 2000). In CDOC, absence of treatment infrastructure for sewage pollutes the water bodies into which it is discharged and could endanger public health and aquatic ecosystems. Unfortunately, the sewage also contains various urban wastes from gasoline stations, photo shops, laboratories, and small industries. These can contribute heavy metals and other toxic compounds that are not suitable for agriculture. A strategy must be developed for a win-win solution that avoids creating pollution while providing farmers with water.

Industry sectors could potentially use sufficiently treated sewage. Since sewage is discharged continuously throughout the year, wastewater is a reliable source of water for industry (Cristóvão et al. 2012). In many developed countries, industries collaborate with the local water agency to use partly treated sewage. The intersectoral impact is even greater where the effluent is discharged to the Macajalar Bay. Simply appropriating water from existing rural uses for transfer to cities and industries will cause rural resentment (Becken 2014). Fisheries and other aquatic ecosystems are particularly sensitive to water quality and can be seriously affected when industrial and municipal effluents are discharged into water bodies. The harm may travel up the food chain when other aquatic life or people eat the affected fish. Similarly, livestock require water for drinking and fodder, and milk is especially susceptible to poor quality water (Meinzen-dick and Appasamy 2000).

Climate crisis and Anthropocene linkages

Floodwater attenuation

The function of preventing the adverse effects of flooding is very important for humans. Watersheds can temporarily store large amounts of water during floods and mitigate the damage to agriculture and settlements. The watershed has the ability to store floodwater and gradually recharge, after the flood, thereby reducing the flood peak. This function is performed at an optimal level in ecosystems found in higher parts of the catchment, where the floods occur, and in watershed areas that are a recipient of torrential flow. The factors on which the efficiency of the function depends are: a) the type of wetland and the morphology of the catchment, b) the location and size of the catchment, c) a channel of water, d) water movement, and e) the vegetation cover (Konishi 2011; Mabao and Cabahug 2014; Zheng et al. 2008).

In the case of CDORB, this function is considered particularly important given the high degree of flooding vulnerability of communities along the river basin. Flooding in CDOR usually affects urban areas in the city. High flood risk communities in Cagayan de Oro are the island bars, old river channels/creeks, and former oxbow lakes such as Isla de Oro, an island community formed through accumulation of silt and sand; Isla Delta and Isla Bugnaw; portions of barangay Consolacion, Tibasak, Cala-cala, and Biasong; and riverbanks in barangay Kauswagan, Carmen, Macasandig, Balulang, Cabula, Mambuaya, and Dansolihon.

Based on statistics from the Philippine Astronomical, Geophysical and Atmospheric Services Administration (PAGASA), only six typhoons hit the entire island of Mindanao in the last fifteen years. CDOR experienced severe flooding in 2009, which displaced 5,684 families or over 30,000 people. In that year, according to PAGASA, the city received an amount of rainfall that was 142 percent above the normal average. According to the National Disaster Coordinating Council (NDCC) and field Report of the Regional Disaster Coordinating Council (RDCC) of Region 10, the total damage was placed at PHP 5.6 million.

To date, the most devastating typhoon occurred in 2011 when Tropical Storm Sendong (Washi) hit Mindanao, particularly CDOC, Iligan City, and other neighboring municipalities. The PAGASA weather station recorded 180.9 mm one-day rainfall, which exceeds the monthly average of only 117 mm. The maximum flood height was 7 to 9 meters in comparison to the normal height of the river. The Department of Public Works and Highways (DPWH) predicted that the return period for a flood event like TS Sendong is around 75 years, but the storm event that triggered it was categorized as having a 20-year return period for its volume of rain. A year later, TS Pablo hit Northern Mindanao including Cagayan de Oro City. The recorded flood height in CDORB reached 7.65 m. This time, the effective utilization of early warning systems in the various communities along the CDORB resulted in zero casualties. Total estimated direct damages and losses due to the TS Sendong in Cagayan de Oro City was at PHP 3.6 billion (Table 2). This estimate does not include the value of the lives lost and the resulting losses in potential income as a result of the aftermath.

TABLE 6. Summary of Total Damages in all Sectors (in PHP)

SECTOR	DAMAGES	LOSSES	TOTAL
Housing	906,576,310.00	110,640,050.00	1,017,216,360.00
Education	56,535.00	–	56,535.00
Health	2,469,631.10	–	2,469,631.10
Infrastructure	1,872,072,000.00	55,990,000.00	1,928,062,000.00
Productive Sector	637,750,000.00	–	637,750,000.00
Tourism	17,780,000.00	315,000.00	18,095,000.00
Grand Total	3,436,704,476.10	166,945,050.00	3,603,649,526.10

Source: Data from National Disaster Coordinating Council (2009)

Understanding the different permutations and scenarios which could play out in CDORB is imperative to be better prepared in the future, according to a study by Mabao and Cabahug (2014). The results showed that the flood inundation of the Cagayan de Oro River is exposed to a high level of flooding hazard. The study also estimated that the river channel is only capable of handling two- or five-year storms without having considerable floodplain. It forecasted the high probability that the city will be flooded again with this category in the next five years. The study recommended that long-term mitigation measures have to be made upstream(Mabao and Cabahug 2014).

Droughts

Of equal importance for consideration is the issue of drought contingencies. Droughts have been experienced in the city more frequently in the recent years: in 2015–2016, 2018, and 2019 (City Agriculture Office 2019). Groundwater is therefore likely to be overpumped during droughts to compensate for surface water deficiency. If the drought lasts for only one or two years, subsequent wetter years may largely replenish the losses in groundwater storage that result from the overpumping and diminished recharge during the drought. A series of drought years, however, may eventually lead to serious depletion of groundwater storage, with consequences for both short and long-term water supply (CCAFS SEA 2016; Kiunsi 2013; Sun and Vose 2016). Because of the uncertainty of future droughts, and the unknown effect on water supply caused by possible climate change, it is important to consider the probability and effect of drought years.

Policy Recommendations for Meeting Urban Water Needs in the Anthropocene and the Implications on Forest Conservation in the CDORB

Ecosystem Services and Biodiversity

Healthy watersheds provide an array of other ecosystem services such as increased biodiversity. Watersheds are vital in maintaining habitat for many of the world's plants and animals. They are home to 80 percent the world's terrestrial biodiversity, which includes complex webs of organisms that include plants and animals, as well as fungi and bacteria. Many of the species that live in forests cannot live anywhere else. Well-managed forests can restore and expand wildlife habitat that supports species threatened by climate change and development (Hilborn 2016; Lambert 2003; Luck, Chan, and Fay 2009; Lynch et al. 2016; Nguyen et al. 2016; Sauer et al. 2008; R. P. Tan et al. 2018).

On this basis it is assumed that there is richness of biodiversity at the CDORB. A survey on biological environment was carried out by the Protected Areas and Wildlife Bureau (PAWB) in 2013, which identified 82 species belonging to 38 different families of plants from the Kagay-an Bridge in barangay Nazareth to Pelaez Bridge in barangay Indahag. Mangrove forests developed along both banks of Cagayan de Oro River and a marshy area exist at the west side of the river mouth. Census surveys identified that a total of 27 species of wildlife vertebrates can be found in the project area, which is 12 km of river length from the river mouth. As for aquatic biota, 21 species of phytoplankton, 7 species of zooplankton, 5 species of macro-invertebrates, and 6 species of fish were identified in CDORB.

Another study on species richness and riparian vegetation along the downstream of Cagayan de Oro River revealed a total of 97 species belonging to 81 genera and 52 families. The study also revealed six threatened species both locally and nationally. Of these threatened species, 5 were considered vulnerable, 1 endangered, and 4 endemic species. Majority of the plant species (63.3 percent) that were identified within the study area have economic value (Lubos et al. 2016).

The wide array of critical ecosystem services provided by healthy watersheds is frequently undervalued when making land use decisions. In the context of CDORB, Tan et al. (2018) conducted a study on the total economic valuation (TEV) of the CDORB for CDOC households in the downstream communities. The research employed the contingent valuation method (CVM), a survey-based approach to valuing non-market goods such as environmental goods and services. CDO households were asked in a contingent valuation survey of their willingness to pay (WTP) or contribute to watershed rehabilitation and preservation efforts to ensure the steady flow of ecosystem services from the CDORB. It was based on the notion that a well-protected watershed can provide security of water supply, fish supply, recreation, biodiversity, flood control, and increased resilience to extreme weather events to the general public, especially those in the downstream communities, which stand to benefit substantially.

A total sample of 963 respondents from the 80 barangays were asked in the CVM survey through face-to-face interviews with the household head or the member making expenditure decisions in the family. Systematic sampling procedure was employed in selecting the respondents in each barangay. The number of respondents in each barangay was set in proportion to the share of the barangay in the total CDO city population.

The non-parametric estimate of the mean WTP for the CDORB rehabilitation and preservation program is 12.19 percent to 17.58 percent of the water bill. The mean monthly water bill per household is PHP 531.80, which means that the WTP is equivalent to between PHP 63.72 and PHP 90.27. With a total household population of 137,465 in CDO (PSA 2010), the total value of the benefits (stable supply of good quality water, flood control, fishing and recreational value, biodiversity) that can be derived from the rehabilitation and preservation of the CDO River Basin would be between PHP 8,911,364.00–12,851,663.00 (USD 197,591.00– 284,959.00) per month or PHP 106,936,365.00–154,219,960.00 (USD 2,371,094.00–3,419,511.00) per year.

The estimates of the various functions and values of the CDORB ecosystem can serve as the basis and justification for the contributions that may be potentially collected from different economic sectors and social groups benefiting from the CDORB's ecosystem services. Benefits derived by the different economic sectors from the CDO River Basin warrant the watershed's preservation activities.

Arguments for Pricing

Water valuation aids policymakers in making both allocation as well as pricing decisions. Pricing of water is important not only for making optimal use of the resource, but also to ensure the financial sustainability of the water agency.

There is growing literature on the political economy of water pricing. Given the strain on public budgets, water agencies will face a difficult choice in the long run: either allow the infrastructure to deteriorate, or make the politically unpopular decision to price water efficiently for all sectors (Almaden 2014).

Households, especially those in the downstream communities, benefit from the CDORB ecosystem in terms of stable supply of good-quality water, flood control, food supply (fish and other seafood), recreation (white water rafting and other water sports activities in CDO River and Macajalar Bay), power supply, climate change mitigation, and biodiversity.

The National Water Resources Board (NWRB), an agency under DENR, is responsible for the administration and enforcement of the 1976 Water Code, which is the legal framework for Water Resource Management (WRM) in the country. NWRB's mandate ranges from regulation, conservation, and protection. It issues all permits for purposes of domestic, municipal, irrigation, power generation, fisheries, livestock raising, industrial, recreational, and other purposes.

NWRB requires one-time application and filing fees for water permits and imposes annual water charges on water permit holders classified according to the type of water use shown in Table 7. The fees are based on volume of water permits, that is, the granted discharge rate, not on actual rate of extraction.

TABLE 7. NRWB Annual Water Charges Based on Volume of Water Permits

CLASSIFICATION	WITHDRAWAL COST/LPS (IN PHP)				
	BASE COST	NOT MORE THAN 10 LPS	MORE THAN 10 LPS BUT NOT EXCEEDING 50 LPS	MORE THAN 50 LPS BUT NOT EXCEEDING 7,000 LPS	MORE THAN 7,000 LPS
a) Municipal					
(1) Level I and II	500	6.60	10.20	13.20	16.80
(2) Level III	5,000	6.60	10.20	13.20	16.80
b) Fisheries	500	3.30	5.10	6.60	8.40
c) Livestock	500	3.30	5.10	6.60	8.40
d) Irrigation					
(1)Communal/ Individual	500	3.30	5.10	6.60	8.40
(2) National/ Corporation	5,000	6.60	10.20	13.20	16.80
e) Power Generation	5,000	3.30	5.10	6.60	8.40
f) Industrial	5,000	12.30	18.95	24.55	30.55
g) Recreation	5,000	12.30	18.95	24.55	30.55

TABLE 7 (CONT'D)

h) Others	5,000	12.30	18.95	24.55	30.55
i) Charge for over extraction for non-critical areas	PHP 3,000 for every 1 lps or fraction thereof over-extracted				
j) Other Charges					
(j-1) Use of Water at its Natural Location for Fish Culture					
(j-1-a) For surface area < 15 has.	Base Cost of PHP 500 + PHP 110/ha				
(j-1-b) For surface area > 15 has.	Base Cost of PHP 500 + PHP 1,650 for 15 ha plus PHP 0.65/ha in excess of 15 ha				
k) Waterworks Supervision					
(k-1) Supervising/ Regulation Fee	PHP 0.50 per PHP 100 capital stock subscribed or paid or if no shares have been issued, of the capital invested, or of the property and equipment, whichever is higher.				

As noted by the study of Palanca-Tan in 2011, groundwater abstraction has increased considerably over the last few decades in CDOC, many of which are undocumented. Groundwater development has thus taken place in an institutional setting that placed no or few limits on groundwater use. This may be attributed to the absence of a NWRB office in the region. To date, there is only one NWRB office in Mindanao—located in Davao City. As a result, the annual water charge is collected only from those who had applied for and been granted the water permit. The schedule of payment depends on the date the permit was granted. It is doubtful, given the very lean manpower base of NWRB and the distribution of permit holders all over the Philippines, that payments of annual water charges are adequately monitored.

Aside from granting of permits, efficient pricing of water consumption is equally as important since it defines the credibility and the quality of water supply as well as the possibility of developing new programs for the satisfaction of future quantitative and qualitative needs (Almaden 2014).

The NWRB water rate structure comprises two parts: the minimum charge and the commodity charge. The minimum charge is also known as service charge or demand charge. It should be able to cover all the fixed costs required to carry on the vital water supply functions not directly related to production and distribution. It ensures that there will be enough revenue to meet the utility's basic costs during periods of low water sales, such as when there is a drought.

The minimum charge should be within the ability of low-income users to pay for 10 m^3 of water. This volume is assumed to be enough for the basic needs of a low-income user. The minimum charge should not exceed 5 percent of the family earnings of the low-income group in the municipality where the water utility operates.

The commodity charge is the amount to be charged for consumption beyond the minimum charge. This amount varies according to volume produced and consumer category. The quantity block method is being adapted as the method used to convert the determined revenue requirements into the tariff structure to be implemented. This supports NWRB's policy to promote conservation of water by providing for higher tariffs for higher consumption.

The Local Water Utilities Administration (LWUA) also has its own procedures for tariff determination which can be found in its Manual on Water Rates and Related Practices, revised in February 2000. The manual presents the fundamentals of the rate-making process and related practices and serves as a resource that the policymaker or manager may draw on to guide the analysis of the validity of rates and the basis on which they are founded.

Under the manual, water rates are set at amounts that ensure recovery of the cost of operating the water system services plus all maintenance costs considering the rate of inflation, and it is considered that they must be set at proper rational levels reflecting public services. It covers everyone from high-volume users to low-income earners, but it is necessary to set water rates that ensure fairness in considering low-income earners. At minimum water meter diameter supply connections of 13 mm, rates must not exceed 5 percent of the income of low-income groups within the water supply.

The CDOWD's water tariff rates were customarily determined by the following factors: cost of systems expansion, operation and maintenance costs, number of connectors, debt service needs of the water district, and operating efficiency. Water rates are implemented only after they are presented in a public hearing and after review and approval by LWUA. Water rates are also set through a socialized pricing scheme. Big water users such as industries and commercial establishments are charged higher rates which, in effect, subsidizes the smaller but more numerous water consumers. The CDOWD is currently implementing the existing water rates approved in 17 June 2011 per LWUA-BOT Resolution No. 84, which took effect on 01 May 2014 (Table 8).

As noted in the previous sections, a number of private firms which include large private service providers as well as small-scale independent providers (SSIPs) such as real estate developers and homeowners' associations in CDOC maintain their own water system, and as such, implement their own water tariff rates. Nonetheless, they follow relatively the same scheme as the CDOWD (Table 9).

In most cases, the water service providers in CDOC follow the direct cost pricing principle. In contrast, the ideal pricing scheme should follow the full-cost pricing approach which entails reflecting the marginal cost of extraction, delivery, and operation, and the environmental and user costs of water extraction and consumption. The efficiency condition also requires that

TABLE 8. Cagayan de Oro Water District Existing Water Rates

CLASSIFICATION	METER SIZE	MINIMUM CHARGE (PHP)	COMMODITY CHARGE			
			11–20 M³	21–30 M³	31–40 M³	≥ 41 M³
Residential/ Government	1/2”	218.40	30.55	31.85	33.65	36.00
	3/4”	349.40	30.55	31.85	33.65	36.00
	1”	698.85	30.55	31.85	33.65	36.00
	1 1/2”	1,747.20	30.55	31.85	33.65	36.00
	2”	4,368.00	30.55	31.85	33.65	36.00
	3”	7,862.40	30.55	31.85	33.65	36.00
	4”	15,724.80	30.55	31.85	33.65	36.00
	10”	60, 278.40	30.55	31.85	33.65	36.00
Commercial/ Industrial	1/2”	436.80	61.10	63.70	67.30	72.00
	3/4”	698.80	61.10	63.70	67.30	72.00
	1”	1,397.70	61.10	63.70	67.30	72.00
	1 1/2”	3,494.40	61.10	63.70	67.30	72.00
	2”	8,736.00	61.10	63.70	67.30	72.00
	3”	15,724.80	61.10	63.70	67.30	72.00
	4”	31,449.60	61.10	63.70	67.30	72.00
	10”	120,556.80	61.10	63.70	67.30	72.00

TABLE 9. Water Rates in Selected Subdivisions in Cagayan de Oro City

RESIDENTIAL WATER RATES	MINIMUM CHARGE (10 M³)	RATE FOR EACH ADDITIONAL CONSUMPTION (PER M³)
High-rise Condominium	260	30.00
High-End Subdivision	275	28.90
High-End Subdivision	250	30.00

the marginal benefit from the use of the resource is equal across all sectors. However, in the case of tariff-setting in the Philippines, it was the base cost which was uniformly charged to all sectors.

A related charge is the environmental user fee based on the principle "let the polluter pay." A fee must be imposed to users depending on the discharge of polluting effluents into the water body. Such a fee is levied in the Laguna Lake Development Authority area. The current approach to water pricing is inadequate for reflecting the true value of water. The fees charged by NWRB for either ground or surface water are grossly insufficient with regard to providing for cost recovery and sustainability of water resources (UNESCAP 2006).

Institutional Mechanisms

Under the 1987 Constitution, all lands in the public domain belong to the State (Art. 7, Sec. 2). The overall jurisdiction and authority over forestlands, grazing lands, and forest reservations including watershed reservations were placed primary responsibility of the Department of Environment and Natural Resources (DENR) thru the Executive Order 192 of 1987.

The DENR is not only responsible for watershed management and water quality but also serves as the lead agency in promulgating the rules and regulations for the control of water, air, and land pollution and ambient and effluent standards for water and air quality. DENR also has an implementing agency called the River Basin Control Office (RBCO) which oversees the implementation, monitoring, and evaluation of DENR's programs and projects within the country's river basin. According to its website, "The RBCO, as lead government agency, rationalizes and integrates all national plans, projects, and programs within the country's river catchments basins, with the authority to serve as the oversight office of all various government agencies and corporations with relevant and related river basin initiatives, projects, and programs such as river basin infrastructure development, flood control, environmental protection, and integrated water resources management" (DENR-RBCO n.d).

Within the CDORB, DENR also coordinates the preparation of the national development plans and investment programs for irrigation with another agency, the National Irrigation Administration (NIA) under the Department of Agriculture (DA), which is responsible for construction and management of irrigation systems. A related agency under DA is the Bureau of Soils and Water Management (BSWM), another national government agency mandated to help protect watersheds. One of BSWM's current watershed management programs is the generation of soil and water technologies that would make farming more productive, profitable, and ecologically sustainable. The National Power Corporation (NPC) is another agency which is given the management and control of the watershed within CDORB for its use. It has the responsibility of watershed protection, development, management, and rehabilitation.

At the local level, the Local Government Units (LGUs) under the Department of Interior and Local Government (DILG) by virtue of the Local Government Code of 1991 (Republic Act 7160) are mandated to implement local initiatives relating to environmental management, including watershed management. The DILG also assists the LGUs in supplying water to many small towns, in some cases with oversight from the LWUA, which finances and oversees autonomous Water Districts (WDs) whose board members are appointed by local mayors. It also provides technical advisory services, institutional support to LGUs and Water Service Providers (WSPs), and design standards for water supplied by water districts and other providers.

There are recently enacted laws that have placed jurisdiction in the CDORB area under different government agencies, which include the National Integrated Protected Areas System (NIPAS Act, RA 7586); the Philippine Mining Act (RA 7942), lodged primarily in the Mines and Geosciences Bureau of DENR; the Indigenous Peoples' Rights Act (RA 8371), and the National Commission on Indigenous Peoples (NCIP). There are currently more than thirty government institutions involved either in forests and water resource management or regulation, which is a main challenge to be addressed.

The Cagayan de Oro River Basin Management Council (CDORBMC)

Created in 16 November 2010 during a Multi-Stakeholders Meeting and Workshop organized by the Archdiocese of Cagayan de Oro and the DENR, the Cagayan de Oro River Basin Management Council (CDORBMC) is a "multi-stakeholder group of [National] Government Agencies (NGAs), Local Government Units (LGUs), Non-Government Organizations (NGOs), private sectors, religious groups, People's Organization/Indigenous People (PO/IP), Security and Academes that converge together to protect, preserve, rehabilitate and manage the watersheds, rivers, and forests" of the CDORB (Roa-Quiaoit 2019). The CDORBMC seeks to improve the quality of life of the stakeholders by upholding and implementing appropriate interventions to enhance better utilization of natural resources and to boost biodiversity along the watersheds and the rivers. It also encourages all other stakeholders to become part of the formulation of management plans and strategies for the river basin.

Currently, CDORBMC is being headed by a Board of Stakeholders (BOS), the decision-making body of the Council, and supported by an Executive Committee (ExeCom) and operated by the Project Management Office (PMO). There are six Technical Working Groups (TWGs), namely: Rehabilitation, Local Governance, Community Development, Resource Management, Payments for Ecosystem Services, and Media Camp and Communications.

Financially, the Council gets support from the NGAs members, in particular DENR 10, DILG 10 and MinDA. For almost a decade, it has also received substantial grants from the Government of The Netherlands through project supports from the International Union for the Conservation of Nature in Netherlands (IUCN-NL). One of its major projects was the implementation of the river basin-wide Payments for Ecosystem Services (PES), socially marketed as VEST – Valuing Ecosystem Services Together, with indigenous peoples as sellers of the ecosystem services of providing water and controlling flooding to the downstream buyers in the urban city (Roa-Quiaoit 2019).

One of its unique features is its lens on the landscape-seascape continuum adapting the ridge, river, reef (R3 program) management is presently realized with the alliance of three existing management bodies in the entire landscape-seascape, namely, Macajalar Bay Development Alliance (MBDA), Cagayan de Oro River Basin Management Council (CDORBMC) and the Tagoloan River Basin Management Council (TRBMC). As of now, CDORBMC is overseeing the implementation of the Integrated River Basin Management and Development Master Plan (IRBMDMP) which was completed in 2014 for Cagayan de Or River Basin. (Roa-Quiaoit 2019).

The implementation of a river basin-wide PES on different modalities are implemented in partnership with both LGU and NGO-based groups (Talama Fund of Kitanglad Integerated NGOs, Sacred Compact of UniFrutti/Hineleban Foundation Inc.) (Roa-Quiaoit 2019).

River basin management councils are increasingly promoted because they are expected to improve resource management and enable participants to engage freely and equally in management. A number of studies noted three mechanisms by which participation enhances river basin management: 1) providing space for consensus building for better quality decisions, 2) mobilization of social capital for better quality decisions and implementation of strategies, and 3) raising the legitimacy of decisions to facilitate implementation of strategies (Almaden 2015; Brown et al. 1990; Chen et al. 2005; Lambert 2003; Wang et al. 2014). However, river basin management councils are also faced by several complexities associated with each of the mechanisms that add challenges to realizing the expectations of participation. They include consensus building and conflict in power relationships between participants; motivating participants that benefits from participation exceed the costs; and defining criteria for legitimate decision that satisfy all participants (Brown et al. 1990; Chen et al. 2005; Macharia, Thenya, and Ndiritu 2010; Rola and Francisco 2004; Sun and Vose 2016).

Tenurial Instruments for Forestland and Resource Management

Security of tenure provides communities with an incentive to invest in sustainable management of their lands, waters, and other resources (Boquiren 2004). Forest tenurial instruments are used by governments to allocate public forests and forest lands to interested individuals, organizations, or entities and put these areas into sustainable management. The trend of forest tenure policies in the country has moved from resource extraction in the early years to the promotion of forest conservation in present times.

Different programs of DENR allow occupancy and tenure over areas within the CDORB. Tenurial instruments include the Community-based

Forest Management Agreement (CBFMA), Industrial Forest Management Agreement (IFMA), Socialized Industrial Forest Management Agreement (SIFMA), and Forest Land Grazing Management Agreement (FLGMA). Duration of tenure is 25 years, renewable for another 25 years. LGUs also award tenure over devolved areas.

Ancestral domain claims are the most dominant tenurial arrangement within the watershed area in CDOC. There are five upstream barangays in CDOC (Besigan, Dansolihon, Mambuaya, Tagpangi, and Tignapoloan) which are home to indigenous peoples greatly dependent on the watershed's water, fisheries, wildlife, timber, and non-timber products for sustenance and survival. This is followed by a CBFMA covering 212.93 ha and an FLGMA with a total area of about 117 ha.

Conclusion

The review and analysis on the sustainability issues of the various downstream users in CDORB provides insights on how competing demands for water are likely to play out in different settings. Cagayan de Oro City's water-dependent sectors rely on a number of ecosystem services that are critical for sustaining its growth and expansion. The CDORB's ecosystem services as a whole are under serious threats in the Anthropocene. Freshwater availability and supply are increasingly unreliable due to pollution, depletion of groundwater, and increasing incidence of extreme weather events. Further, export of the costs of ecosystem service exploitation from the upstream and downstream areas of the basin have dire consequences not only for CDOC but for the entire region. Population growth and urbanization contribute directly to the decline of watershed hydrological services and the absence of a sewerage system adds to water pollution problems. Piecemeal reactions and responses do not work on undesirable disruptions in water supply, like the threats brought about by climate change and extreme weather events such as flooding and droughts.

There are pressing concerns in CDOC that must be urgently attended to. The Poblacion barangays of CDOC, which are home to 82 percent of its population, are faced with competing uses of water for domestic, municipal, industrial, and commercial purposes. Moreover, these are also areas where major flooding in the city frequently occurs. Densification of economic activities may be cost-efficient for utility providers, but expanding productive activities in the area may put more stress on attaining environmental integrity.

The traditional result has been intersectoral competition over quantity and quality of water, but there are also possibilities for mutual gain. A closer look at types of water uses shows that domestic, agricultural, and industrial demands for water are all found in both rural and urban areas in different concentrations.

Demand management will also be necessary. A more rational system for raw water pricing that considers environmental, economic, and social costs and benefits should be instituted in order to achieve more efficient and equitable water resource allocation. It should provide the necessary incentives to the users in order to effectively utilize water resources and consequently to contribute to the achievement of the relevant environmental targets. A study on the total economic valuation of the CDORB has provided empirical evidence that CDOC residents have substantial willingness to pay, which can serve as basis and justification for instituting market-based contributions that may be potentially collected from different economic sectors and social groups benefiting from the CDORB's ecosystem services. It will also encourage different users to employ technologies and implement efficient water use practices. Water pricing, which has received considerable attention as a means of demand management, may not be very effective without complementary regulations, education campaigns, leak detection, retrofitting, recycling, and other technical improvements. The current status of groundwater depletion in CDOC may be controlled to a substantial extent by addressing inefficiencies in the LGU-operated system and the main water provider of the city, the CDOWD. The high transaction costs of monitoring illegal abstractors and collecting water charges from vast numbers of users is a critical issue.

In CDOC, appropriate response strategies for improving groundwater governance are still inadequate and this needs further attention in terms of filling information gaps, identifying solutions through exchange of experiences, and policy interventions. To better assess ecosystem services of the CDORB, future ecohydrological studies need to better account for the scaling effects of natural and anthropogenic stressors and other water supply and demand processes.

There are a number of challenges in dealing with transboundary water bodies governed by multiple agencies such as rivers and aquifers in today's hydrologic and political landscape, like the case of the CDORB. For the CDOC downstream community that shares the watershed with four other jurisdictions, it is vastly beneficial to come to a collaboration with various institutions that cross traditional political borders. Decision-makers need to identify the linkages between the watershed and people and be cognizant of the spatial and temporal relationship between ecosystem functions, services, and beneficiaries. Mapping areas for management interventions for ecosystem services will help beneficiaries understand how they gain from the decisions, and—from a financing perspective—who might be willing to pay or need to be compensated for practice changes. There is a need to understand the full scope for trade-offs and externalities. Ecosystems are multifunctional and contribute to multiple ecosystem services in potentially conflicting ways. To avoid inconsistencies, there is a need to develop a conceptual map that shows the causal chain from forest management decisions to ecosystem services and benefits that accrue to different users. There is also a need to understand what incentives currently link ecosystem services to people and where there are policy gaps and opportunities.

In this Anthropocene epoch, an increased capacity to reflect on the actions of multiple users and determine how they can be changed is needed to secure economic and sustainable development in the CDORB.

References

Almaden, C. R. C. 2014. Protecting the Water Supply: The Philippine Experience. *Journal of Social, Political, and Economic Studies* 39 (4): 467–493.

———. 2015. Management Regimes of River Basin Organisations. *Environmental Policy and Law* 45 (3/4): 156–162.

———. 2017. A Case Study on the Socio-Economic Conditions of the Artisanal Fisheries in the Cagayan de Oro River. *International Journal of Social Ecology and Sustainable Development* 8 (2): 14–30. https://doi.org/10.4018/IJSESD.2017040102.

———. 2018. Ecotourism Policy Options for the White Water Rafting in Cagayan de Oro River, Philippines: A Multi-Criteria Analysis. *International Journal of Tourism Policy* 8 (2): 108–128. https://doi.org/10.1504/IJTP.2018.092469.

Aromataris, E. and D. Riitano. 2014. Constructing a Search Strategy and Searching for Evidence. *Systematic Reviews* 114 (5): 49–56. https://doi.org/10.1097/01.NAJ.0000446779.99522.f6.

ADB (Asian Development Bank). 2013. *Water Supply and Sanitation Sector Assessment, Strategy, and Road Map*. Manila: Asian Development Bank.

Becken, S. 2014. Water Equity – Contrasting Tourism Water Use With That of the Local Community. *Water Resources and Industry* 7–8: 9–22. https://doi.org/10.1016/j.wri.2014.09.002.

Boquiren, R. R. 2004. Rewards for Environmental Services in the Philippines Uplands: Constraints and Opportunities for Institutional Reform, 1–59. World Agroforestry (ICRAF). https://www.worldagroforestry.org/publication/rewards-environmental-services-philippine-uplands-constraints-and-opportunities.

Brown, A., A. Dayal, and C. Rumbaitis Del Rio. 2012. From Practice to Theory: Emerging Lessons from Asia for Building Urban Climate Change Resilience. *Environment and Urbanization* 24 (2): 531–556. https://doi.org/10.1177/0956247812456490.

Brown, T. C., B. L. Harding, and E. A. Payton. 1990. Marginal Economic Value of Streamflow: A Case Study for the Colorado River Basin. *Water Resources Research* 26 (12): 2845–2859. https://doi.org/10.1029/WR026i012p02845.

Carr, G. 2015. Stakeholder and Public Participation in River Basin Management—An Introduction. *Wiley Interdisciplinary Reviews: Water* 2 (4): 393–405. https://doi.org/10.1002/wat2.1086.

Cagayan de Oro City Agriculture Office. 2017. "Area of Crops Harvested in Cagayan de Oro City."

———. 2019. City Agricultural Development Plan 2019–2022. City Government of Cagayan de Oro City. https://cagayandeoro.gov.ph/phocadownloadpap/announcement/City_Agricultural_Development_Plan_2019_2022.pdf.

CESM (Center for Environmental Studies and Management). 2014. "Formulation of an Integrated River Basin Management and Development Master Plan for Cagayan De Oro River Basin." https://faspselib.denr.gov.ph/sites/default/files//DOCUMENTS/cagayan%20de%20oro%20DRAFT%20MASTER%20PLAN.pdf.

CCAFS SEA (CGIAR Research Program on Climate Change, Agriculture and Food Security–Southeast Asia). 2016. Assessment Report: The Drought and Salinity Intrusion in the Mekong River Delta of Vietnam. 25–28 April. Ben Tre, Tra Vinh, Kien Giang, Vietnam. https://hdl.handle.net/10568/75633.

CDOWD (Cagayan de Oro City Water District). 2015. Vulnerability Assessment, vol. 12.

Chen, C. H., W. L. Liu, S. L. Liaw, and C. H. Yu. 2005. Development of a Dynamic Strategy Planning Theory and System for Sustainable River Basin Land Use Management. *Science of the Total Environment* 346 (1–3): 17–37. https://doi.org/10.1016/j.scitotenv.2004.12.057.

Cities Development Initiative for Asia. 2013. Pre-Feasibility Study on Wastewater, Watershed & Solid Waste Management Cagayan de Oro City, Philippines. https://www.fsmtoolbox.com/assets/pdf/198.pdf.

Clifton, J., and S. Foale. 2017. Extracting Ideology from Policy: Analysing the Social Construction of Conservation Priorities in the Coral Triangle Region. *Marine Policy* 82 (August): 189–196. https://doi.org/10.1016/j.marpol.2017.03.018

Cristóvão, R., C. Botelho, R. Martins, and R. Boaventura. 2012. Pollution Prevention and Wastewater Treatment in fish Canning Industries of Northern Portugal. *International Proceedings of Chemical, Biological and Environmental Engineering* 32 (1): 12–16. https://doi.org/10.7763/IPCBEE.

Dan Gavriletea, M. 2017. Environmental Impacts of Sand Exploitation. Analysis of Sand Market. *Sustainability (Switzerland)* 9 (7): 118. https://doi.org/10.3390/su9071118.

DENR-RBCO (DENR-River Basin Control Office). n.d. "Power & Function." http://riverbasin.denr.gov.ph/main/index.

Dziegielewski, B. 2003. Strategies for Managing Water Demand. *University Council on Water Resources, Water Resources Update* 126: 29–39. http://opensiuc.lib.siu.edu/cgi/viewcontent.cgi?article=1110&context=jcwre.

Falkenmark, M., L. Wang-Erlandsson, and J. Rockström. 2019. Understanding of Water Resilience in the Anthropocene. *Journal of Hydrology X* (2): 100009. https://doi.org/10.1016/j.hydroa.2018.100009.

Gleick, P. H., and M. Palaniappan. 2010. Peak Water Limits to Freshwater Withdrawal and Use. *Proceedings of the National Academy of Sciences of the United States of America*, 107 (25): 11155–11162. https://doi.org/10.1073/pnas.1004812107.

Grimaldi, M., V. Pellecchia, and I. Fasolino. 2017. Urban Plan and Water Infrastructures Planning: A Methodology Based on Spatial ANP. *Sustainability (Switzerland)* 9 (5): 1–23. https://doi.org/10.3390/su9050771.

Helweg, O. J. 2000. Water Supply and Groundwater Issues in Developing Countries. *Water International* 25 (1): 33–39. https://doi.org/10.1080/02508060008686795.

Hilborn, R. (2016). Correlation and Causation in Fisheries and Watershed Management. *Fisheries* 41 (1): 18–25. https://doi.org/10.1080/03632415.2016.1119600.

Israel, D. 2001. The Silent Dangers of Quarrying. *Philippine Institute of Development Studies Policy Notes* No. 2001-05. http://dirp3.pids.gov.ph/ris/pdf/pidspn0105.pdf

JICA (Japan International Cooperation Agency). 2014. Special Assistance for Project Sustainability for Cagayan de Oro City Water District for Provincial Cities Water Supply Project Phase III: Final Report. https://openjicareport.jica.go.jp/pdf/12182564_01.pdf.

Joachim, O. I., N. Kamarudin, G. U. Aliagha, and K. J. Ufere. 2015. Theoretical Explanations of Environmental Motivations and Expectations of Clients on Green Building Demand and Investment. *IOP Conference Series: Earth and Environmental Science* 23 (012010). https://doi.org/10.1088/1755-1315/23/1/012010.

Kiunsi, R. 2013. The Constraints on Climate Change Adaptation in a City With a Large Development Deficit: The Case of Dar es Salaam. *Environment and Urbanization* 25 (2): 321–337. https://doi.org/10.1177/0956247813489617.

Konishi, T. 2011. Climate Change on the Vietnam, Mekong Delta Expected Impacts and Adaptations. Food and Agriculture Organization (FAO). http://www.fao.org/fileadmin/templates/rome2007initiative/FAO_WB_TCIO_CC_Meeting_May_2011/TORUKO_1. pdf.

Lambert, A. 2003. Economic Valuation of Wetlands: An Important Component of Wetland Management Strategies at the River Basin Scale. Ramsar Convention Secretariat. UNEP/GEF South China Sea Project. http://www.unepscs.org/Economic_Valuation_Training_Materials/06%20Readings%20on%20Economic%20Valuation%20of%20Coastal%20Habitats/07-Economic-Valuation-Wetlands-Management.pdf.

Leigh, N. G. and H. Lee. 2019. Sustainable and Resilient Urban Water Systems: The Role of Decentralization and Planning. *Sustainability (Switzerland)* 11 (3). https://doi.org/10.3390/su11030918.

Li, Y. 2013. Analysis of Urban Water Use and Urban Consumptive Water Use in Nebraska – Case Study in the City of Lincoln, Grand Island and Sidney. MCRP thesis, University of

Nebraska, 91. https://digitalcommons.unl.edu/arch_crp_theses/22/.

Lieske, D. J. 2015. Coping With Climate Change: The Role of Spatial Decision Support Tools in Facilitating Community Adaptation. *Environmental Modelling and Software* 68: 98–109. https://doi.org/10.1016/j.envsoft.2015.02.005.

Loomis, J., P. Kent, L. Strange, K. Fausch, and A. Covich. 2000. Measuring the Total Economic Value of Restoring Ecosystem Services in an Impaired River Basin: Results From a Contingent Valuation Survey. *Ecological Economics* 33 (1): 103–117. https://doi.org/10.1016/S0921-8009(99)00131-7.

Lubos, L. C., V. B. Amoroso, F. Coritico, and M. Demetillo. 2016. Species Richness and Riparian Vegetation of Plants in Cagayan de Oro River, Mindanao, Philippines. *Asian Journal of Biodiversity* 6 (2). https://doi.org/10.7828/ajob.v7i1.839.

Luck, G. W., K. M. A. Chan, and J. P. Fay. 2009. Protecting Ecosystem Services and Biodiversity in the World's Watersheds. *Conservation Letters* 2 (4): 179–188. https://doi.org/10.1111/j.1755-263x.2009.00064.x.

Lynch, A. J., S. J. Cooke, A. M. Deines, S. D. Bower, D. B. Bunnell, I. G. Cowx, V. M. Nguyen, J. Nohner, K. Phouthavong, B. Riley, M. W. Rogers, W. W. Taylor, W. Woelmer, S. J. Youn, and T. D. Beard. 2016. The Social, Economic, and Environmental Importance of Inland Fish and Fisheries. *Environmental Reviews* 24 (2): 115–121. https://doi.org/10.1139/er-2015-0064.

Mabao, K. and R. G. Cabahug. 2014. Assessment and Analysis of the Floodplain of Cagayan De Oro River Basin. *Mindanao Journal of Science and Technology 12*, 147–170. https://mjst.ustp.edu.ph/index.php/mjst/article/view/47.

Macharia, J. M., T. Thenya, and G. G. Ndiritu. 2010. Management of Highland Wetlands in Central Kenya: The Importance of Community Education, Awareness and Eco-Tourism in Biodiversity Conservation. *Biodiversity* 11 (July) : 85–90. https://doi.org/10.1080/14888386.2010.9712652.

McGrane, S. J. (2016). Impacts of Urbanisation on Hydrological and Water Quality Dynamics, and Urban Water Management: A Review. *Hydrological Sciences Journal*, 61 (13): 2295–2311. https://doi.org/10.1080/02626667.2015.1128084.

Meinzen-dick, R. and P. P. Appasamy. 2000. Urbanization and Intersectoral Competition for Water. *Urbanization and Water*, 27–51.

Molle, F. and J. Berkoff. 2009. Cities vs. Agriculture: A Review of Intersectoral Water Re-Allocation. *Natural Resources Forum* 33 (1): 6–18. https://doi.org/10.1111/j.1477-8947.2009.01204.x.

National Disaster Coordinating Council. 2009. Consolidated Report on the Effects of Flash Floods in Cagayan de Oro City, 9 February 2009.

Nguyen, V. M., A. J. Lynch, N. Young, I. G. Cowx, T. D. Beard, W. W. Taylor, and S. J. Cooke. 2016. To Manage Inland Fisheries Is to Manage at the Social-Ecological Watershed Scale. *Journal of Environmental Management* 181 (October): 312–325. https://doi.org/10.1016/j.jenvman.2016.06.045.

NWRB (National Water Resources Board). 2019. "Permitted Groundwater Extractions by User/Category."

Palanca-Tan, R. (2011). Designing a Raw Water Fee Scheme for Groundwater Extraction in Cagayan de Oro , Philippines. The Economy and Environment Program for Southeast Asia (EEPSEA). https://archium.ateneo.edu/economics-faculty-pubs/104/.

Postel, S. L., and B. H. Thompson. 2005. Watershed Protection: Capturing the Benefits of Nature's Water Supply Services. *Natural Resources Forum* 29 (2): 98–108. https://doi.org/10.1111/j.1477-8947.2005.00119.x.

PSA (Philippine Statistics Authority). 2010. Census of Population and Housing. https://psa.gov.ph/sites/default/files/CAGAYAN%20DE%20ORO%20CITY_FINAL%20PDF.pdf.

Ravanera, R. 2001. A Case Documentation ff the SARD Initiative Implemented by ANGOC in the Uplands of Dansolihon, Cagayan de Oro City, Philippines. Asian NGO Coalition for Agrarian Reform and Rural Development (ANGOC). http://www.fao.org/tempref/docrep/fao/009/ag256e/ag256e00.pdf.

Roa-Quiaoit, H. A. 2019. “About Us.” Cagayan de Oro River Basin Management Council. https://www.cdorbmc.com/about-us/.

Rola, A. C., J. M. Pulhin, and A. H. Rosalie. 2018. Water Policy in the Philippines. *Global Issues in Water Policy* 8. https://doi.org/https://doi.org/10.1007/978-3-319-70969-7.

Rola, A. and H. Francisco. 2004. Realities of Watershed Management in the Philippines: Synthesis of Case Studies. *Philippine Institute for Development Studies Discussion Paper Series* No. 2004-24 (July). https://dirp3.pids.gov.ph/ris/dps/pidsdps0424.pdf.

Satterthwaite, D. 2011. How Urban Societies Can Adapt to Resource Shortage and Climate Change. *Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences* 369 (1942): 1762–1783. https://doi.org/10.1098/rsta.2010.0350.

Sauer, T. J., R. B. Alexander, J. V. Brahana, and R. A. Smith. 2008. The Importance and Role of Watersheds in the Transport of Nitrogen. *Nitrogen in the Environment*, 203–240. https://doi.org/10.1016/B978-0-12-374347-3.00008-1.

Shrestha, A., D. Roth, and D. Joshi. 2018. Flows of Change: Dynamic Water Rights and Water Access in Peri-Urban Kathmandu. *Ecology and Society* 23 (2): 42. https://doi.org/10.5751/ES-10085-230242.

Sjödin, J., A. Zaeske, and J. Joyce. 2016. Pricing Instruments for Sustainable Water Management. Working Paper Nr. 28, *SIWI, Stockholm*, 13. https://www.siwi.org/publications/pricing-instruments-for-sustainable-water-management/.

Stoker, P., H. Chang, E. Wentz, B. Crow-Miller, G. Jehle, and M. Bonnette. 2019. Building Water-Efficient Cities: A Comparative Analysis of How the Built Environment Influences Water Use in Four Western U.S. Cities. *Journal of the American Planning Association* 85 (4): 511–524. https://doi.org/10.1080/01944363.2019.1638817

Strzepek, K. and B. Boehlert. 2010. Competition for Water for the Food System. *Philosophical Transactions of the Royal Society B: Biological Sciences* 365 (1554): 2927–2940. https://doi.org/10.1098/rstb.2010.0152.

Sun, G. and J. M. Vose. 2016. Forest Management Challenges for Sustaining Water Resources in the Anthropocene. *Forests* 7 (3): 1–13. https://doi.org/10.3390/f7030068.

Tan, M. P. 2017. Sedimentation Dynamics of the Cagayan de Oro River Catchment and the Implications for its Coastal Marine Environments. PhD diss., The University of Notre Dame Australia. https://researchonline.nd.edu.au/theses/165.

Tan, R. P., C. R. C. Almaden, M. K. D. Navarro, M. M. Obedencio, and C. L. R. Sereñas. 2018. Total Economic Value of the Cagayan de Oro River Basin. In *Innovation Addressing Climate Change Challenges*, edited by M. Hymel, K. Larry, J. Milne, and H. Ashiabor, vol. 1, 169–184. Cheltenham, UK: Edward Elgar Publishing Limited. https://doi.org/10.4337/9781788973366.

UNESCAP (United Nations Economic and Social Commission for Asia and the Pacific). 2006. “Good Practices on Strategic Planning and Management of Water Resources in Asia and the Pacific.” Water Resources Series No. 85. https://www.unescap.org/sites/default/files/Water%20Resources%20Series%20No85.pdf.

United Nations Environment Program (UNEP). 2014. Sand, Rarer than One Thinks. https://wedocs.unep.org/handle/20.500.11822/8665.

UNWTO (World Tourism Organization). 2012. Global Report on City Tourism. AM Reports, vol. 6, 2–53. https://www.unwto.org/archive/middle-east/publication/global-report-city-tourism.

Wang, Z., Y. Luo, M. Zhang, and J. Xia. 2014. Quantitative Evaluation of Sustainable Development and Eco-Environmental Carrying Capacity in Water-Deficient Regions: A Case Study in the Haihe River Basin, China. *Journal of Integrative Agriculture* 13 (1): 195–206. https://doi.org/10.1016/S2095-3119(13)60423-2.

Welcomme, R. L., I. G. Cowx, D. Coates, C. Béné, S. Funge-Smith, A. Halls, and K. Lorenzen. 2010. Inland Capture Fisheries. *Philosophical Transactions of the Royal Society B:*

Biological Sciences 365 (1554): 2881–2896. https://doi.org/10.1098/rstb.2010.0168.

Zheng, B., J. Duan, J. Jia, F. Liu, and Y. Yan. 2008. Assessment of Ecosystem Services of Lugu Lake Watershed. *International Journal of Sustainable Development and World Ecology* 15 (1): 62–70. https://doi.org/10.1080/13504500809469770.

Zomer, R. J., A. Trabucco, D. A. Bossio, and L. V. Verchot. 2008. Climate Change Mitigation: A Spatial Analysis of Global Land Suitability for Clean Development Mechanism Afforestation and Reforestation. *Agriculture, Ecosystems and Environment* 126 (1–2): 67–80. https://doi.org/10.1016/j.agee.2008.01.014.