WATER, FOOD, AND ENERGY IN SORSOGON CITY, PHILIPPINES:

Understanding Urban-Rural Metabolic Flows

UN environment

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Acronyms

BAWASA	Barangay Water and Sanitation Association
CAO	City Agriculture Office
CASO	City Agricultural Services Office
CENRO	City Environment and Natural Resources Office
CLUP	Comprehensive Land Use Plan
DA	Department of Agriculture (Philippines)
DEWATS	Decentralized Water Treatment System
FLUP	Forest Land Use Plan
GI-REC	Global Initiative for Resource Efficient Cities
ISWMP	Integrated Solid Waste Management Plan
LGU	Local Government Units
MJ	Megajoules
NIA	National Irrigation Administration
NRW	Non-Revenue Water
PCA	Philippine Coconut Authority
PSA	Philippine Statistics Authority
SCWD	Sorsogon City Water District
SWIP	Small Water Impounding Project
STW	Shallow Tube Wells
SUWECO	Sorsogon Water Electric Cooperative Inc.
UNEP	United Nations Environment Programme

Table of Contents

Introduction

Sorsogon City, is a second-class component city[1] in the Province of Sorsogon, classified as partially urban with a total land area of 31,292 hectares with 18 of its 64 *barangays*[2] classified as urban. As the city rapidly urbanizes, the flows of its metabolism may have an impact on the quality of life of its constituents especially if it continues business as usual. Rapid urbanization has brought opportunities and threats to the quality of life of its people. Some of these threats are resource scarcity, health and sanitation, energy and food shortages, environmental issues, and climate change.

The challenges created by the process of urbanization should be seen as an opportunity to further its transition to a sustainable region. It is imperative that the local government unit (LGU) come up with management strategies to address the challenges and undefined risks brought about by urbanism. Creative thinking must be given priority to come up with proactive ideas on how to maximize the use of the raw materials in the city and transform waste materials into new products must be generated to spur a better economy and environment for its constituents.

This study was conducted to better understand the resource flows of the city through an urban metabolism analysis. The study looks at the flows of water and food in the city. Flow analysis identifies possible intervention points and provides recommendations that the city can take to stem the tide of unsustainable urbanization.

Methodology

Experts used the framework developed by the Global Initiative for Resource Efficient Cities and looked at the material flows for water, construction materials, energy, and food. Through this initial stock-taking and analysis of the resource flows in Sorsogon City, the experts, the city, and project managers from the League of Cities of the Philippines and the United Nations Environment Programme determined that the intricately connected resource flows of food and water are the most important in the city of Sorsogon. Thus, these became the focus of the study.

For the analysis, experts used a simplified version of Sabine Barle's (2009) method—which is based on the determination of the main inputs and outputs of the system under consideration. It assumes that the inputs should be equal to the sum of the utilization and outputs.

Inputs	Utilization	Outputs
Local extraction	Material throughput	To nature (local)
Imports	Recycling	To nature (exported)

The methodology applied in this study follows the framework of Barles (2009) and the Statistical Office of the European Communities (Eurostat, 2001). However, it focuses only on food and water, and the materials related to its production and consumption in the city.

To understand the flow of materials related to food production and consumption, Sorsogon City is regarded as a system that produces and consumes using the material balance principle, such that the flow of materials related to the production and consumption of food within the city is considered via the relationship:

1 The Philippines classifies cities/municipalities by "classes" which are based on the total annual revenue. This classification was done by the Philippine Department of Finance. For more information, see: http://www.nscb.gov.ph/activestats/psgc/articles/con_income.asp

2 "Barangays" are sub-municipal level administrative entities in the Philippines.

Total Inputs = Total Outputs + Net Accumulation/Consumption

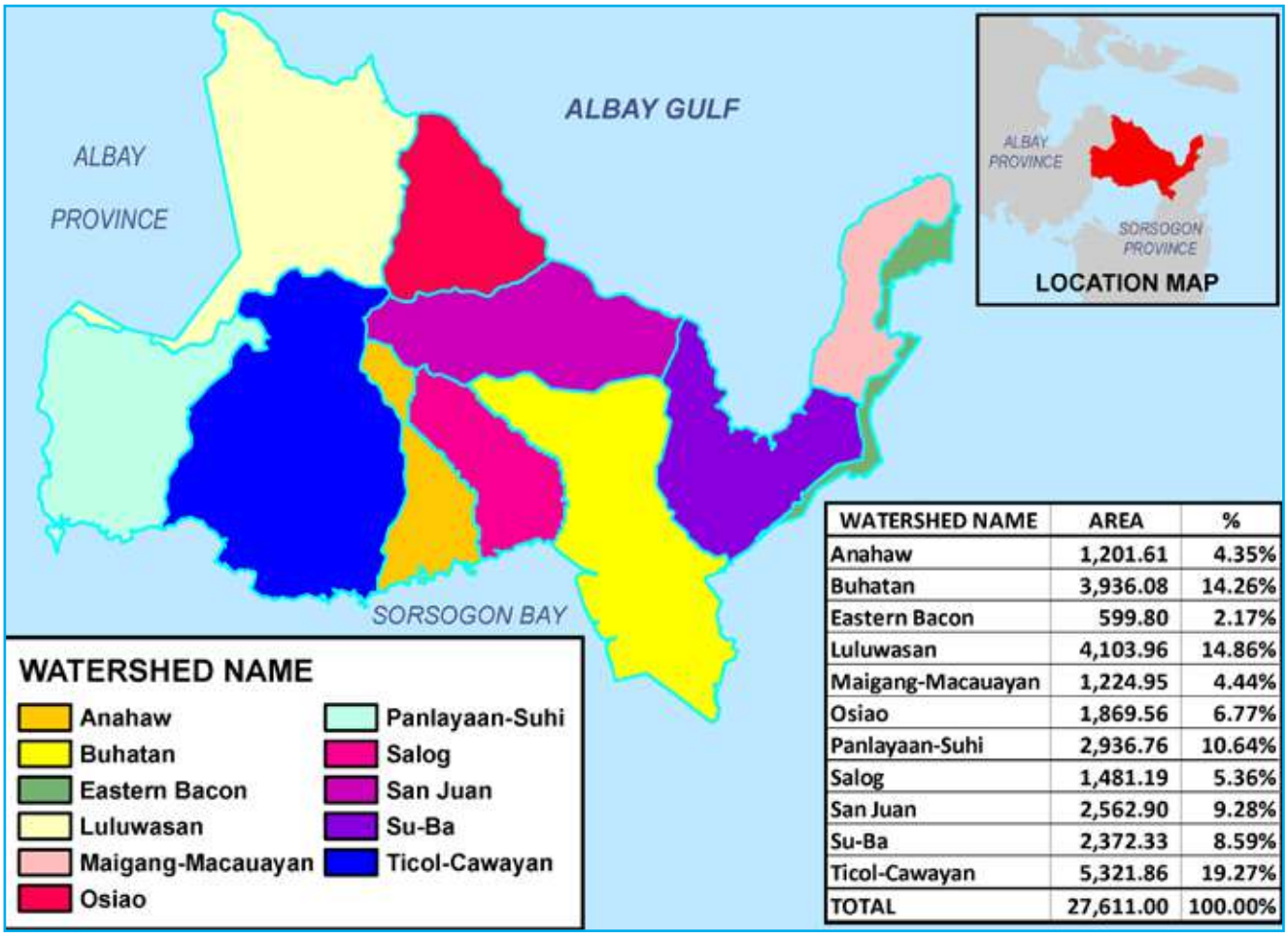
The same formula is used for water.

Material flow accounting for water

The first resource that the study focuses on is water. This resource is essential to every facet of the City of Sorsogon's economic and societal development endeavors; and its importance cannot be over-emphasized. Sorsogon City taps its water resources for irrigation, power generation, domestic, commercial and industrial consumption; and, to a lesser degree, tourism and aquaculture. The sole source of water that supplies the surface and groundwater resources of the city is rain. The amount of water available for extraction is highly dependent on the topography and other relevant physical characteristics of the place such as the soil texture, land cover and land use, and slope, among others. Climate also plays a vital role in the temporal and spatial availability of water in the city.

A. System boundary

To understand comprehensively how the water resources in the city are extracted and utilized, it is essential that the system boundary be established. It is important to consider the topographic conditions that dictates the quantity and availability of water in the different locales of the city (i.e. the watersheds or sub-watersheds). A watershed's boundary (also called '*divide*') is dependent on the topography, and thus does not necessarily coincide with the political boundary of a city. The figure and table below show the 11 sub-watersheds in the city of Sorsogon and the area encompassed by the divides of each watershed.



WATERSHED NAME	AREA	%
Anahaw	1,201.61	4.35%
Buhatan	3,936.08	14.26%
Eastern Bacon	599.80	2.17%
Luluwasan	4,103.96	14.86%
Maigang-Macauayan	1,224.95	4.44%
Osiao	1,869.56	6.77%
Panlayaan-Suhi	2,936.76	10.64%
Salog	1,481.19	5.36%
San Juan	2,562.90	9.28%
Su-Ba	2,372.33	8.59%
Ticol-Cawayan	5,321.86	19.27%
TOTAL	27,611.00	100.00%

Figure 1.0: Sorsogon City Sub-Watershed

B. Water demand in the city

The water resources in Sorsogon City are used for irrigation, power generation, domestic, commercial and industrial consumption.

Irrigation - As of the year 2015 there are eleven (11) communal irrigation systems in the city. These are gravity type systems. Some rice producing areas are also irrigated using shallow tube wells (STWs) with groundwater at its source.

Power generation - The Cawayan Hydroelectric Plant in Guinlajon, West District is the only hydropower generating power plant operating in the city at present. During June and July, the flow in the river is not sufficient, the power plant cannot operate at full capacity, according to interviewed personnel at the plant.

Domestic, industrial and commercial water consumption - The Sorsogon City Water District (SCWD) runs the city's waterworks system and supplies the domestic, industrial and commercial needs of the citizens of Sorsogon. It supplies 62% of the demand while the remaining 38% is supplied by Barangay Water and Sanitation Associations or BAWASAs. The SCWD extracts water from springs, groundwater and surface water to supply the needs of the city.

C. Material flow analysis

For the material flow analysis, only the water that is actively extracted will be considered as inflow in the system. There is no record of water extraction and consumption in the areas not covered by the SCWD, so only an estimate of the consumption of these areas is presented. An estimate of water used for irrigation by gravity is made using available data on rice production and the irrigation infrastructure in place. Irrigation from other systems such as shallow tube wells (STWs) and small water impounding projects (SWIPs) have been excluded due to insufficiency of information. Likewise, precipitation in rain-fed rice fields is not considered since it is not actively extracted. The figure below shows the material flow of water resources in the city of Sorsogon.

Input - The total material inputs for water extraction and consumption within Sorsogon City were obtained using the production data from the SCWD and the Sorsogon Water Electric Cooperative Inc. (SUWECO). The sources of input considered in this material balance are the Cawayan Mini Hydro-electric Power Plant, SCWD extraction, and water diverted from the river using dams and gravity irrigation systems.

Output - The total material outputs were derived from the same datasets and account for the water outfall from the Cawayan Mini Hydro-electric Power Plant, the estimated outflow from households and institutional and commercial establishments, and crop evapotranspiration.

INPUT		SOCIETY/ECONOMY		OUTPUT	
Local Extraction	126 193.98 ktons/yr	**Material Throughput (Local Consumption)**	65 959.19 ktons/yr	**Balancing outputs**	- ktons/yr
				Unused Local Extraction	ktons/yr
				To Nature (Local)	60 234.78 ktons/yr
Imports	- ktons/yr			**To Nature (Exported)**	- ktons/yr
				Exports	- ktons/yr
	126 193.98 ktons/yr		**65 959.19 ktons/yr**		**60 234.78 ktons/yr**

Figure 2: Material flow analysis of Water in Sorsogon City

Table 4: Different input account items

INPUT	TONS/YR		REMARKS
LOCAL EXTRACTION			
Hydro-electric power plant inflow	27 721 323.00	tons/ yr	*Source:* SUWECO Inc
SCWD Annual Production Volume (Direct from Source)	3 394 116.00	tons/ yr	*Source:* SCWD
Annual Production Volume from Non-SCWD Sources (BAWASA etc)	1 209 600.00	tons/ yr	*Source:* SCWD
Irrigation Water Diverted from Source	93 868 939.93	tons/ yr	*Source:* NIA, CASO
TOTAL	**126 193 978.93**	**tons/ yr**	

Table 5: Different output account items

OUTPUT	TONS/YR	
TO NATURE (Local)		
Emissions to air & water		
Hydro-electric power plant outflow	27 721 323.00	tons/yr
Wastes		
SCWD Consumers		
• WW from Domestic or household plumbing	1 976 570.00	tons/yr
• WW from Commercial & Industrial plumbing (Not treated)	292 351.95	tons/yr
• WW from Commercial & Industrial plumbing (Treated - DEWATS)	32 850.00	tons/yr
• WW from Commercial & Industrial plumbing (Treated - Slaughterhouse)	4 136.05	tons/yr
WW from Institutional Plumbing	177 438.00	tons/yr
WW from Non-SCWD consumers	604 800.00	tons/yr
Rice crop evapotranspiration	35 149 725.60	tons/yr
Dissipative Flow		
SCWD Systems Losses (NRW)	910 770.00	tons/yr
Non-SCWD Systems Losses (NRW)	604 800.00	ttons/yr
Runoff, Percolation, Seepage, Evaporation & Conveyance Losses	58 719 214.33	**tons/yr**
TOTAL	**126 193 978.93**	**tons/yr**

** Water volumes have been converted to equivalent masses using the density of water, 1,000 kgs/m3*

We see that the material flow account is balanced since the total input equals the total output.

D. The Ticol-Cawayan Sub-Watershed

The Sankey diagram below shows the water utilization flow for the Ticol-Cawayan sub-watershed during the year 2016. Surface water provided 98.5% of the water consumed, while the remaining 1.5% came from groundwater extraction. As shown below, the irrigation sector is the major user of water in the sub-watershed, accounting for 95.5% of the total water used during the year. The diagram also shows that, although the power generation sector also utilizes a considerable amount (88.8%) it does not affect the utilization of the other users because its outflow can be readily used by the users downstream,. The surface water treatment plant of SCWD affects the irrigation sector since it is located upstream. However, the amount utilized by the treatment plant would account for only 3.0% of the irrigation water, had it not been diverted to the treatment plant. The diagram also shows that almost 64% of the water diverted to irrigation is not directly utilized by the crops, and comprises the non-consumptive water requirement, as well as the losses due to the inefficiency of the irrigation system. Domestic water requirement comprises 4.5% of the total water utilization for the year. Residential consumers take up the largest chunk of the domestic water demand at 62.5%. The non-revenue water meanwhile, represents 25.9% of the total production of SCWD.

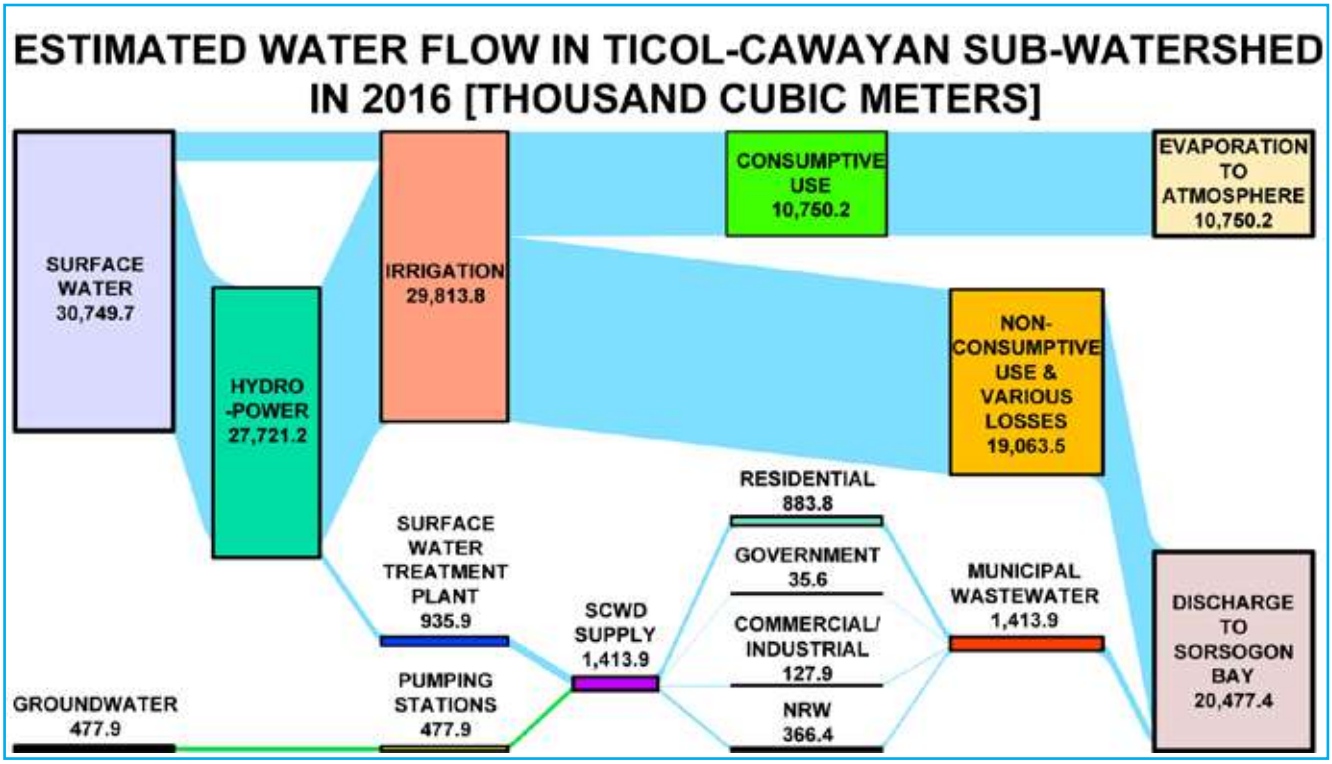


Figure 3: Sankey Diagram of Water Utilization in the Ticol-Cawayan Sub-Watershed

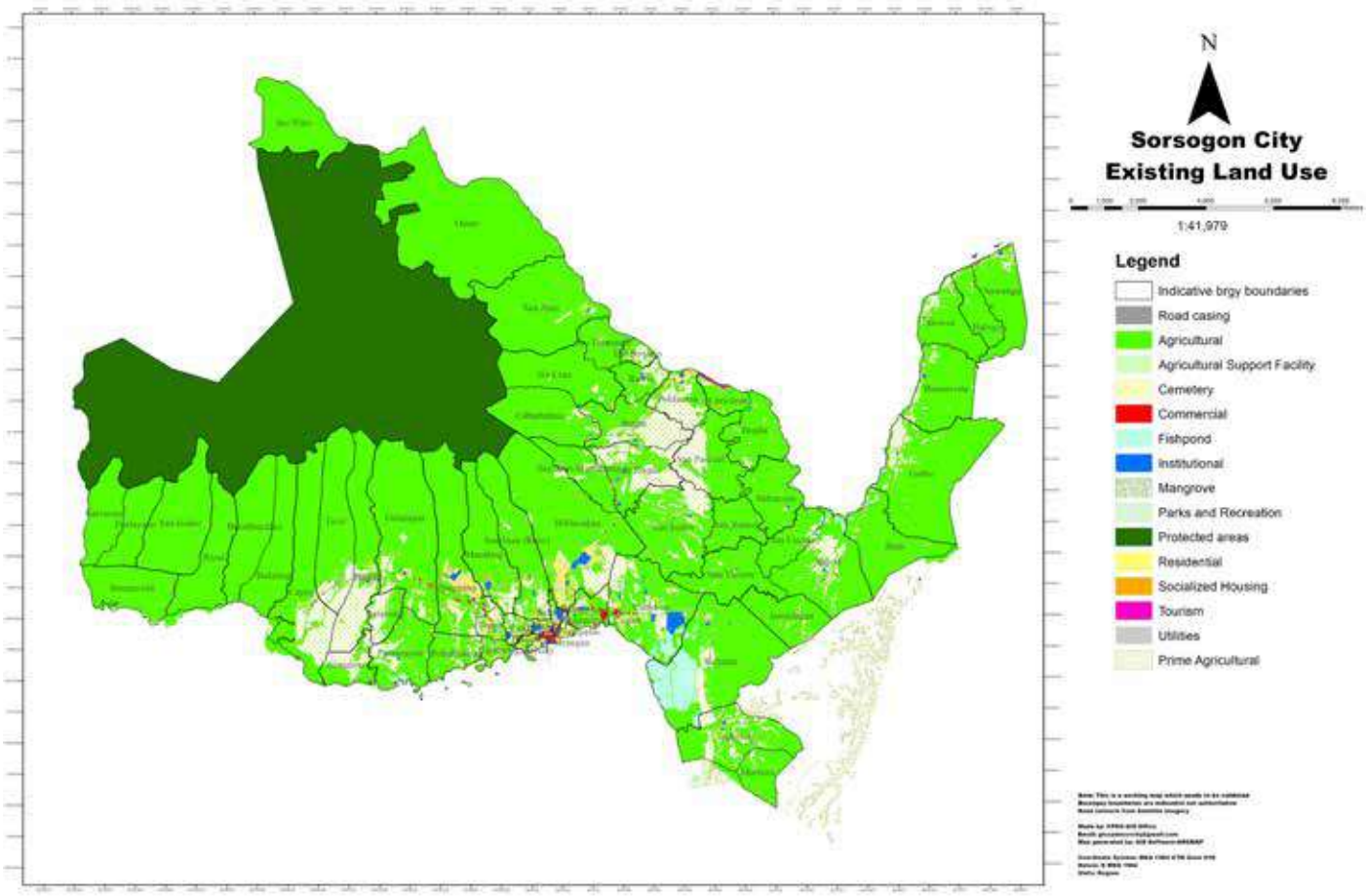


Figure 4: Agricultural Lands and Land Uses in Sorsogon City

Material flow accounting for food

Agriculture is the chief driver of Sorsogon City's economy, with rice, coconut, and pili as the major products. The city is both a producer and consumer of food resources. Local consumption relies on both processed and semi-processed food products from outside and locally produced agricultural products. At the same time, it exports agricultural produce to neighboring municipalities and internationally.

A. System boundary

To understand the flow of food resources in the city, it is important to first define the system boundary, so that the flow of food resources into and out of the city will be properly accounted for. The boundary of the system corresponds to the political boundary of the city. This also includes the municipal waters, where capture fishery is conducted by fishermen. Figure 4 shows the agricultural lands, along with the other land uses.

B. Agricultural products in Sorsogon City

The City Agricultural Services Office (CASO) is the data custodian of the city's agricultural production. The office monitors the production of all major agricultural products within the city, except coconut. Aside from the major and minor agricultural crops, the office also monitors the fishery and aquaculture sector. Tables 6 and 7 show the production for different agricultural commodities, fish, and other aquatic resources in Sorsogon City as sourced from the 2015 national census by the Philippine Statistics Authority (PSA) and the 2012 annual per capita consumption of agricultural commodities for Sorsogon province.

Table 6.0: Agricultural commodity production in 2015

COMMODITY	PRODUCTION [TONS]
Rice & other cereals/grains	20 258.29
Vegetables	660.10
Pili	211.97
TOTAL	21 130.36

Table 7.0: Fishery and aquaculture production in 2015

Communal Waters: Rivers & Creeks (Mt)	Brackish water fish ponds (Mt - 2015)	Inland Municipal Fishery (Mt)	Freshwater Fishpond - Tilapia (2015 - Mt)	Capture Fisheries/ Municipal Fishing						Seaweeds (Mt - 2015)	Green Mussel (Mt - 2015)
				Crab Entangling Nets (Mt)	Fish Gill Nets (Mt)	Trap Net (collapsible) or «Bubo» (Mt)	Fish Corrals (Mt)	Crab Lift Net (Mt)	Compressor/ Hookah Fishing (Mt)		
8.18	29.43	6.2	2.42	16.78	21.34	8.58	22.2	2.46	22.1	0	135.7
3%	11%	2%	1%	6%	8%	3%	8%	1%	8%	0%	49%
TOTAL [tons]											275.38

The Integrated Solid Waste Management Plan of Sorsogon City (2016) reports that food and organic waste comprise 48.34 per cent of the city's total solid waste generation. The same report shows that 14.85 per cent of the municipal solid wastes are food packaging materials. This indicates the degree to which the city relies on imported processed and semi-processed goods. The City Environment and Natural Resources Office (CENRO) is the data custodian for solid waste. However, solid waste accounting and monitoring is not done regularly since the activity requires considerable resources to conduct. Figure 5 shows the different components of the city's solid waste.

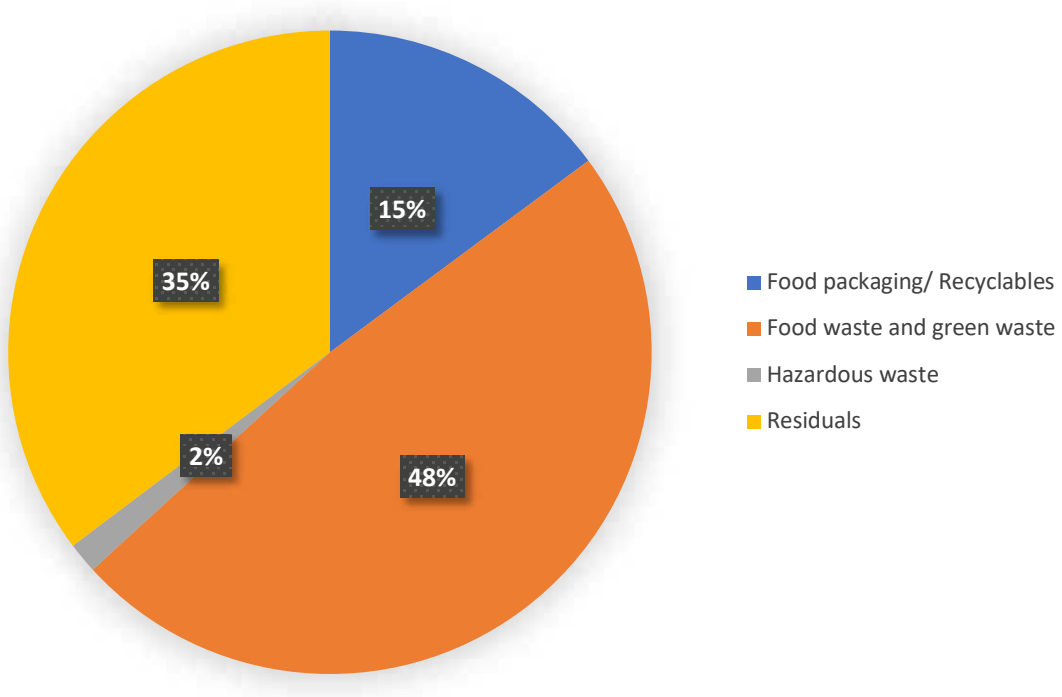


Figure 5: Different components of the city's solid wastes

C. Material flow analysis

The material flow accounting of food in the city illustrates whether the inputs that go into the system are either accumulated (or consumed) within the city or are leaving the city as an output.

Figure 6 shows the metabolic flow of food resources in the city of Sorsogon.

INPUT		SOCIETY/ECONOMY		OUTPUT	
Local Extraction	21.41 ktons/yr	**Material Throughput (Local Consumption)**	29.81 ktons/yr		
				To Nature	11.29 ktons/yr
Imports	20.33 ktons/yr				
				Exports	0.64 ktons/yr
	41.74 ktons/yr		**29.81 ktons/yr**		**11.93 ktons/yr**

Figure 6: Food MFA of Sorsogon City

Inputs – The total material inputs for food production and consumption within Sorsogon City include local extraction and imports. The CASO has an extensive annual production record of the important agricultural commodities (except coconut) in the city, but there is no reliable data available on food imports from neighboring communities.

Local extraction – These are the materials extracted that are used by the city for final and intermediate processing. In the case of Sorsogon City, this pertains to the local production of agricultural commodities, including fishery and aquaculture products.

Imports – To make up for the lack of data on imports, the values are approximated by assuming that the local traders or market system in the city reacts to the shortfall in the food supply by importing that which the local farmers cannot produce. Thus, the import volume arrived at in this analysis is the difference between the total food consumption and the total food production.

Table 8 shows the different items considered in the input account.

Table 8: Inputs for food production and consumption in Sorsogon City

INPUT			REMARKS
Local Extraction			
Local Production		tons/yr	*Source:* City Agriculture Services Office
• Rice & other cereals	20 258.29	tons/yr	
• Vegetables	660.10	tons/yr	
• Pili	211.97	tons/yr	
• Poultry, Meat & Dairy Products (no data)			*Possible Source:* City Veterinary Office
• Marine & Aquacultural Products	275.38	tons/yr	*Source:* City Agriculture Services Office
• Coconut (no data)			*Possible Source:* PCA/DA
Agri-wastes generated from production	-	tons/yr	*Possible Source:* CAO/CENRO/DA
Imports			
• Processed & semi-processed goods	20 208.86	tons/yr	Difference between consumption and production
• Imports un-accounted for	125.40	tons/yr	Balancing assumption
TOTAL	**41 740.00**	**tons/yr**	

Outputs – The total material outputs for food production and consumption within Sorsogon City include local emissions to nature and exports. The accounting considered the biomass waste generated in harvest and post-harvest processing, food waste from consumption that ends up at the city dump, and semi-processed goods exported outside of the country, such as pili nut. There is, however, no available data on the volume of food traded to neighboring towns.

Local emissions to nature – This indicator is comprised of emissions to air and water, wastes, and dissipative flow generated during the consumption of food, including the biodegradable waste component of the city's solid wastes. These resources have the potential to provide massive financial and environmental reward to the city and its inhabitants if converted into useful products and by-products, such as organic fertilizers or soil conditioners.

Exports – Pili, coconut, crab, and other shellfish are the primary export commodities of the city, though export data is only available on pili nut and crabs (including other shellfish).

Table 9 shows the different items considered in the output account:

Table 9: Outputs for food production and consumption in Sorsogon City

OUTPUT			REMARKS
To Nature (Local)			
Biodegradable/Organic portion of Municipal Solid Waste	11 292.13	tons/yr	*Source:* ISWMP
Exports (International/Local/Neighboring Towns)			
• Pili	211.97	tons/yr	Assumption: all pili products are exported
• Crab meat	109.00	tons/yr	*Source:* CAO
• Other fisheries & aquacultural products	317.66	tons/yr	*Source:* CAO
TOTAL	**11 930.75**	**tons/yr**	

Food sector material balance

The numbers on local consumption measurements obtained from the Philippine Statistics Authority (PSA) are assumed to include the food that was consumed and wasted during consumption. It is thus accounted for in the material local throughput section of the table. At the same time, consumption waste was accounted for in the output column via the food and organic waste component of the municipal solid waste as well. Food waste was thus accounted for twice in this table. In order to have a balanced table (input = material throughput + output), the double accounting of the consumed food waste was corrected by subtracting it from the consumption values (the material throughput column).

Input = Material Throughput (Local Consumption) + Output

41.74 ktons = 29.81 ktons + 11.93 ktons

41.74 ktons = 41.74 ktons

The input and output accounts are thus equal. It must be noted however that coconut, a significant agricultural commodity in the city, is not included in the present analysis.

D. Rice production and consumption in Sorsogon City

Rice is the staple food of the people of both Sorsogon City and the Philippines. It is one of the major agricultural products of the city and plays an important role in the urban metabolism of the city. Rice production has a considerable biomass waste byproduct which, when disposed improperly, can emit greenhouse gases or pollute waterways. Rice production requires a considerable amount of irrigation water, while post-harvest processing utilizes electricity and fuel energy. Excess fertilizers applied in rice fields are the primary contributors of non-point nutrient pollutants in surface water brought by run-off water coming from the fields. Thus, rice has the most impact of any of Sorsogon's agricultural commodities in the food, water, and energy sectors of the city's metabolic processes. This study covers rice production and consumption in Sorsogon City for 2016 and uses 2016 production data from the City Agricultural Services Office (CASO) and 2015 census data from PSA.

Production area

Physically, the city has a total rice production area of 2,420.78 hectares as of 2016. Several irrigation systems enable some city farms to have two cropping cycles annually. Thus, for 2016, the effective area for rice production was 4,459.50 hectares.

Material flow analysis

inputs – The total material inputs for rice production and consumption include unused local extraction, local extraction, and imports. The accounting considered rice both as consumed by the city and as production input (seeds), the biomass wastes generated in harvesting and post-harvest processing, and fertilizer as production inputs.

Unused local extraction – These are materials that are extracted in relation to the production and consumption of rice but are not directly consumed or used, including husks, chaff, and other post-harvest waste by-products. According to the CASO, 65 per cent is recovered post-milling. Thus, 35 per cent is assumed to be the unused local extraction.

Local Extraction – These are extracted materials that are used by the city for final and intermediate processing, including the rice produced post-milling and the portion of the *palay* production that has been set aside to be used as seeds for the next growing cycle. Water for irrigation was not included in this account because it is covered in a separate analysis for the water sector.

Imports – To estimate the volume of rice importation, the researchers used population data from the PSA to compute the annual total rice requirement using the annual per capita rice consumption rate of 109.5 kilograms per capita-year. It is assumed that the local rice supply chain would automatically react to any shortfall in supply relative to the demand and, therefore, the input and output sides would be balanced. The difference between the total annual rice consumption and the rice produced within the city is assumed to be the volume of rice imported, which is 5,588.8 metric tons.

Table 10 shows the different items considered in the input account if the city imports rice at the minimum level.

Table 10: Inputs for rice production and consumption in Sorsogon City at minimum rice import level

INPUT		
Balancing Inputs		
Unused Local Extraction		
• Husk, chaff & other post-harvest waste	6 936.55	tons/ yr
Local Extraction		
• Rice Produced within Sorsogon City		
• Consumed by the residents	12 882.16	tons/yr
• Used as seed for next planting season	62.92	tons/yr
• Irrigation Water		tons/yr
Imports		
• Imported Rice for Local Consumption	5 588.80	tons/yr
• Fertilizer (6 bags/ ha)	1 337.85	tons/yr
• Pesticides		tons/yr
TOTAL	**26 808.28**	**tons/yr**

Outputs – The total material outputs for rice production and consumption include unused local extraction, local emissions to nature, and exports. The accounting considered the biomass wastes generated in the harvesting and post-harvest processing, the portion of rice produced by rice traders from neighboring municipalities, and fertilizer and seeds as dissipative flows.

Unused local extraction – These are the materials extracted, but not directly used in the production or consumption of the rice in the city. This indicator is equivalent to the unused local extraction on the input side of the accounting balance.

Local emissions to nature – This indicator is comprised of emissions to air and water, wastes, and dissipative flow. Only dissipative flow was captured in this analysis, comprising fertilizer utilization and seeds for planting.

Exports – No data on the volume of rice traded has been compiled by the CASO. To compute for rice exports, an iterative method is used based on the assumption that the market would automatically react to any shortfall (or excess) in supply by importing (or exporting), and thus balance the input/output sides of the equation.

Table 11 shows the different items considered in the output account at the minimum rice export level.

Table 11: Outputs for rice production and consumption in Sorsogon City if rice is exported at the minimum level

OUTPUT		TONS/YR
BALANCING OUTPUTS		
Unused local extraction		
• Husk, chaff & other post-harvest waste	6 936.55	tons/yr
To Nature (Local)		
Emissions to air & water		
Wastes		
Dissipative Flow		
• Fertlizers	1.337.85	tons/yr
• Seeds	62.92	tons/yr
To nature (exported)		
Exports		
• Rice sold to traders during harvest season	62.92	tons/yr
TOTAL	**8 400.23**	**tons/yr**

The figure below shows the material flow account of rice production and consumption in the City of Sorsogon.

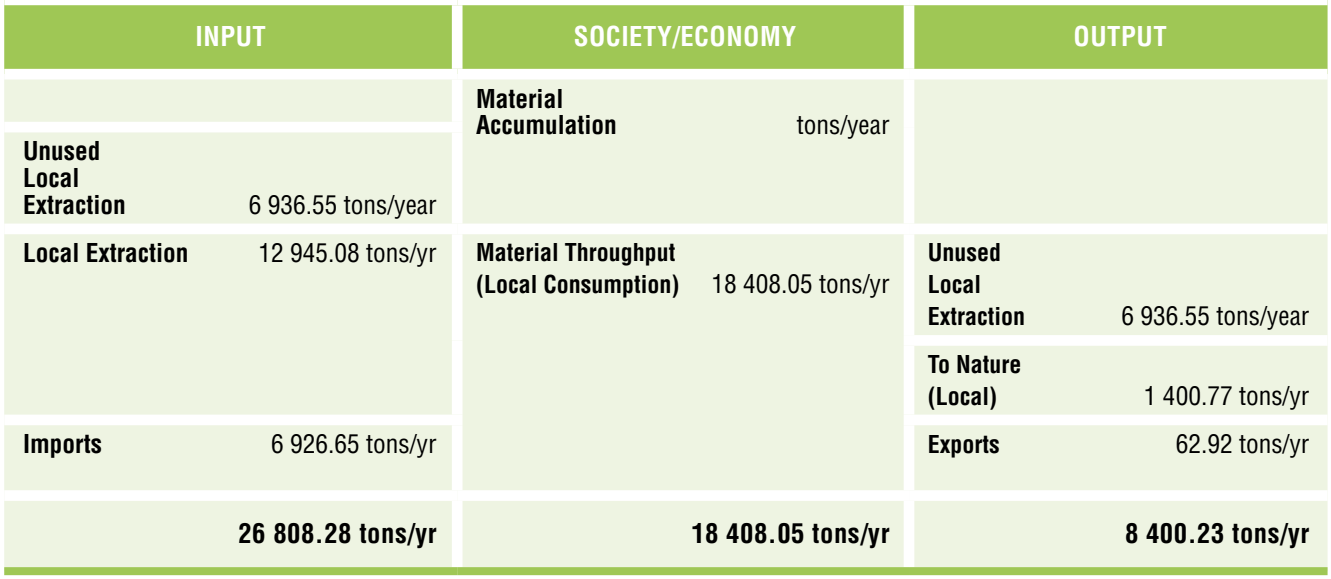


Figure 6: Material flow account of rice production and consumption in Sorsogon City

Energy consumption in rice production

Energy is expended in every step of the interconnected processes involved in producing the rice that the city consumes. Rice production in the city is still predominantly done using manual and animal power, but there are several activities where mechanization has been employed. These processes utilize electric motors and internal combustion engines.

Irrigation

Irrigation water is supplied through irrigation canals and pumps. The researchers made a simplifying assumption that water supplied by irrigation canals has a neutral contribution to the energy account as they flow by the action of gravity alone and that only 50 per cent of the irrigation water is supplied by the pumps.

Post-harvest activities

Threshing in Sorsogon City is typically done using a mechanical thresher. Human energy input is added through the machine operators and various activities such as bagging, hauling, hay separation, and bundling.

Mechanical drying is done on a very limited scale (3 per cent) at present. The rest of the city's rice produce are dried using solar energy on multi-purpose drying pavements and concrete roads. Solar drying energy input in this investigation comes from the energy expended by the farmers in hauling, laying, spreading, and bagging the paddy being dried.

Milling is computed, assuming that the typical rice mill uses an electric motor-powered mill, using the energy coefficient obtained by Leniger (1975).

The rice production energy consumption disaggregated into electricity and diesel fuel consumption are shown in Table 15.

Table 15: Rice production energy consumption from different sources

Energy Consumption in Rice Production [MJ]	
Fuel Energy Consumption (Diesel)	
A. Energy Input from Irrigation Water Application via Pumping	**36 900.00**
B. Threshing Energy Input	**655 374.24**
C. Mechanical Drying Energy Input	**147 284.90**
D. Transportation Energy Input for Rice Produced within the City	**88.10**
Sub-total fuel energy consumption	**839 647.24**
Electricity Energy Consumption	
E. Milling Energy Input	**1 974 163.11**
TOTAL ENERGY CONSUMPTION IN RICE PRODUCTION [MJ]	**2 813 810.36**

Policy recommendations

Sorsogon City can attain sustainable development without putting undue pressure on the environment through appropriate legislation. At present, the city has no local ordinance that pertains directly to urban metabolism. However, through an analysis using the framework of the Global Initiative for Resource Efficient Cities, it was able to understand how resources are utilized within the city. This will help the city craft laws that can accelerate its transition into a resource efficient city.

A. Achieving water efficiency in Sorsogon City

In terms of water resources, Sorsogon City needs to conserve and rehabilitate the sub-watersheds, particularly the Ticol-Cawayan sub-watershed. It must pursue programs and policies that are geared toward its protection and development such as the updating of the Forest Land Use Plan (FLUP), Comprehensive Land Use Plan (CLUP), soil and water conservation in upland agriculture and other related programs. Enabling policies and ordinances may be crafted by the city to support these programs. Apart from the city government, other stakeholders, like the companies operating inside the watershed, must play their role in preserving and improving the sub-watersheds' ecosystem service function through projects such as:

- **Reforestation or revegetation of denuded catchment areas;**
- **Inclusion of sediment and erosion control measures in all road opening and earth moving projects within the catchment area;**
- **Construction of water flow retarding infrastructure (such as check dams) at the upper reaches of the rivers to improve infiltration and groundwater recharge, and help in preventing flooding and excessive siltation downstream;**

The farmers or the irrigators' association could consider a calendar that better aligns with the historical discharge of the irrigation water sources or staggered planting schedules to eliminate water competition. The City Agriculture Office should introduce irrigation efficiency technologies that reduce the over-all irrigation water requirement and thus reduce water loss.

For the rivers to deliver a reliable amount of flow during the dry season, the infiltration of rainfall into the ground must be enhanced by revegetation of bare slopes and controls against erosion to slow down the flow of water during heavy rainfall events. As the population grows, water demand is expected to grow, and the SCWD must develop other water sources to meet that demand. A study should also be conducted of sustainable extraction rates with consideration of possible future resilience challenges.

The Sorsogon Water Electric Cooperative (SUWECO) must protect and rehabilitate the Cawayan river's headwater catchement. To address challenges with excessive siltation and low discharge levels, the SUWECO should take measure to slow the flow of water during heavy rainfall events inside the catchment area. Information from continued hydrologic monitoring of the watershed can be useful in galvanizing people into action, and helpful in avoiding misunderstandings due to demand increase and climate impacts.

B. Achieving food efficiency in Sorsogon City

Rice is the staple food of Filipinos, that is why rice self-sufficiency is of paramount importance to any city in the country. At present, only 70 per cent of the city population's consumption requirements can be supplied by local producers. To avoid future problems, the city should increase irrigation cover and reduce the use of chemical fertilizers, substituting with organic fertilizers from the city's solid waste. This approach will also bring the city a step closer to attaining a circular or circulative urban metabolism.

Conclusion

With an urban population growing at a rate of 1.54%, the impact on Sorsogon City's resources is expected to grow. The elected officials of Sorsogon City have issued and implemented several resolutions and ordinances within the area, including Sorsogon City Organic Agriculture Ordinance of 2010 and the Ecological Solid Waste Management Ordinance of 2005. These ordinances addressed threats of resource scarcity, environmental issues, health, and sanitation. They pioneered organic farming and agriculture, provided climate change response training to local farmers, and enhanced ecological balance through integrated solid waste management. The city is also working closely with the national government to improve irrigation systems and transition to a more circular metabolism with respect to water usage through a multi-stakeholder working group.

Updates from the field

As a result of the piloting, Mayor Sally Ante-Lee formalized the current Project Technical Working Group into a Multi-stakeholder Technical Working Group tasked to lead the rehabilitation of the Ticol-Cawayan sub-watershed. Also, the city is working on updating its Forest Land Use Plan to improve the condition of the 11 watersheds in the city. Lastly, Sorsogon City is negotiating with the National Irrigation Authority to co-finance the building of water catchment facility in the Ticol-Cawayan sub-watershed to store water during rainy season. The city is planning to utilize its budget for relocating informal settler families in the watershed area to co-finance the establishment of the water catchment facility.

To minimize the amount of waste generated by the agriculture sector, the city is strongly advocating for the shift in organic farming. The City Agriculture Office is providing free seeds to farmers, buys the produce, and use the vegetables and crops as ingredients for Sorsogon City's feeding program.

To build the city's database for building materials, the City Engineering Office will require applicants for building permits to itemize the materials used for construction and to provide information where the construction materials are sources and where the used materials are stored.

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WATER, FOOD, AND ENERGY IN SORSOGON CITY, PHILIPPINES:

Understanding Urban-Rural Metabolic Flows

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