MSc Program
Environmental Technology & International Affairs

Assessing Sources and Pathways of Nutrient Pollution in the Coral Triangle

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 08.09.2012

Affidavit

I, **MANHART ANN MARIE**, hereby declare

1. that I am the sole author of the present Master's Thesis, "ASSESSING SOURCES AND PATHWAYS OF NUTRIENT POLLUTION IN THE CORAL TRIANGLE", 132 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 08.09.2012

Signature

This study would not have come into fruition without:
FAO and their numerous reports on agriculture and aquaculture
The Government of Canada's Agri-Food Trade Service who corresponded with me regarding their Southeast Asian Reports

My profuse gratitude to the following professors who have led me to the right research trails:
Prof. Paul Brunner
Prof. Matthias Zessner
Prof. Johann Fellner

This study is dedicated to my husband Georg whose love for marine ecosystems has led him to find me. He has always reminded me that I was born and raised in a tropical paradise. It is my hope that this study will some day somehow contribute to keeping the Coral Triangle the paradise it ought to be.

Ad majorem Dei gloriam

Abstract

This study explores a model depicting N (Nitrogen) and (P) Phosphorus contributions of the Philippines, Malaysia, and Indonesia in the Coral Triangle Large Marine Ecosystem (CTLME). N and P are the precursors to eutrophication and harmful algal blooms, and are threatening the health of the CTLME.

The methodology used in this study is Substance Flow Analysis (SFA). Particularly, sub-systems in the areas of agriculture, aquaculture, and the activity "to nourish" are explored by a mass balance approach. The base year used is 2005. While the total contributions of the three investigated countries are estimated to be 700 kt/a of N and 190 kt/a of P, the study also deals with the contribution of each country and of selected sectors to the CTLME.

The main sources of N and P are excess nutrients from commercial fertilizers in agriculture that accrue as stocks in soils and run-off to rivers; untreated human and animal wastes dumped in waterways; and effluents from aquaculture. A more prudent use of commercial fertilizers and interventions such as landfills and wastewater treatment plants are recommended to decrease the nutrient load in the CTLME.

A knowledge-based body of work is necessary for decisions to save the Coral Triangle. The main result of this study is a consistent methodological approach for establishing the necessary knowledge base in the field of regional nutrient analysis. Additional work to collect better and improved data is needed to verify the conclusions about nutrient loads in the CTLME drawn in this thesis.

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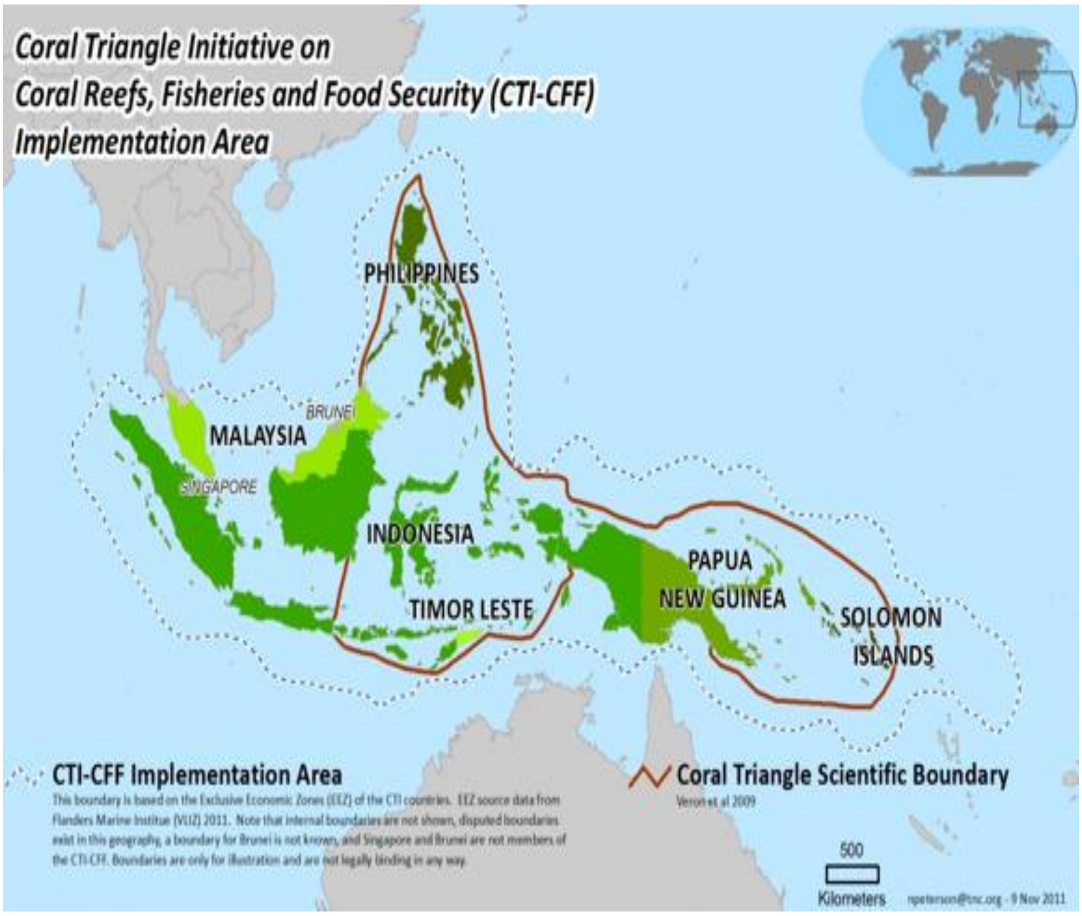
I-Introduction

Background

The Coral Triangle is an area lying in the West Pacific spanning the seas of the Philippines, Malaysia, Indonesia, Timor Leste, Papua New Guinea and the Solomon Islands.

A recent study done by the University of Queensland in Australia in cooperation with WWF (World Wide Fund for Nature) has identified this region to be the "birthplace of the seas," where a significant amount of marine organisms spawn only to travel to different parts of the world. The Coral Triangle encompasses only 1% of the world's oceans, yet it contains 76% of reef-building species and 37% of coral reef fish (Hoegh-Guldberg et.al, 2009).

Figure 1. The Coral Triangle Map



Source: The Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF, 2012)

The Coral Triangle is the epicenter of marine biodiversity in the world, albeit there is no mechanism put in place to ensure its survival. A partnership between the six countries in 2007 brought forth the Coral Triangle Initiative on Coral reefs, Fisheries and Food Security (CTI-CFF, 2012). Yet this partnership is non-legally binding and tackling pollution does not seem to be a main priority.

Close to 150 million inhabitants live in the Coral Triangle and a significant portion are directly dependent on the Coral Triangle for their livelihood and food needs (Hoegh-Guldberg et.al, 2009). Rampant increase in population adds more to the stress in these coastal areas.

A study done by University of Queensland and WWF gave emphasis on the need for concrete action plans beyond the Kyoto Protocol to lower carbon emissions that have affected the Coral Triangle. In the study it is mentioned that carbon dioxide emissions have increased the temperature, in turn bleaching the corals and acidifying the seas. It is also mentioned however, that besides a concrete gesture from the global community, regional efforts should also be done to avert the destruction of this biosphere (Hoegh-Guldberg, et.al., 2009).

Research Goal

Having been a stakeholder in the Coral Triangle and culling from her experiences in the aquaculture industry, the proponent of this study would like to tackle a study on the pollution aspect of this said area. From first hand experience, it is a fact that the absence of water treatment and the disposal of wastes into the sea are the most common causes of pollution afflicting Southeast Asia. An expedition by the California Academy of Sciences to the Verde Island Passage, said to be the one of the most bio-diverse areas in the Coral Triangle resulted in findings that deep-sea fish develop tumors due to untreated human sewage dumped in the sea (California Academy of Sciences, 2012).

Environmentalists, policy makers, NGOs will always attribute pollution as one of the scourges of the Coral Triangle, yet there are no numbers and quantifiable data they could peg. Nitrogen (N) and Phosphorus (P) are substances that are precursors to eutrophication. Eutrophication is a condition wherein nutrients are plentiful in an artificial manner such that they result in an abnormal algal and plankton bloom. This is harmful because in time these algae and plankton decay and contribute to oxygen depletion in the sea. This will then affect reef systems and eventually fish which most of the population rely on for protein needs. N and P are also indicators of pollution because an excess of these nutrients indicate human sewage; agricultural, aqua-cultural and other wastes infiltrating an otherwise pristine marine environment.

Hence, the goal of this study is to trace sources, pathways and sinks of N and P flows quantitatively from relevant countries to the Coral Triangle Large Marine Ecosystem (CTLME). This is a first and important step towards remediation. It allows to set strategic priorities for the reduction of nutrient flows to the CTLME.

Research Questions

This study aims to answer the following:

A. What are the main sources of N and P in the Coral Triangle, particularly for the Philippines, Indonesia and Malaysia?

B. How can these main sources be managed in order to decrease the nutrient load in the Coral Triangle?

Scope and Limitation

Because Timor Leste, Papua New Guinea and the Solomon Islands are still developing, the emerging economies the Philippines, Indonesia, Malaysia, will be the countries subjected to the SFA in detail. Hence in this study's SFA, the N and P from Timor Leste, Solomon Islands and Papua New Guinea will be pegged as zero.

The Philippines, Malaysia and Indonesia are emerging countries and members of the Association of Southeast Asian Nations (ASEAN). They will have the capacity to take the lead in the future through cooperative efforts to halt pollution within the region.

It is also important to consider that these emerging countries saw rapid increases in "large scale pond culture" about 50 years ago, thereby increasing fish and crustacean production (Hoegh-Guldberg, et. al., 2009). The researcher theorizes that this is one of the causes of increase N and P in the CTLME.

Agriculture and aquaculture will be the core sectors to be examined in this study as data on industry use of N and P is as of now very limited. Nonetheless, in the future this study can be extended to take into consideration the rest of the countries as well as all livelihood sectors. It is also necessary to note that in computations of N values of plants in the *Agriculture* Sub-systems, the values were based on Ciba Geigy figures, which are only the edible portions of plants and thus have more protein. This is also the reason why humans tend to eat these parts of plants that have a higher protein concentration. The use of edible portion values may contribute to certain uncertainties in the researcher's estimates.

NH_3 emissions in the air from manure storage, application, and after-use (Zessner, 2012) will not be included in this study, as this requires further research. On the other hand, an estimated percentage of denitrification of N will be included when taking into account the mass of N that is passed on from the rivers to the marine areas.

II-Research Methodology

Mass Flow Analysis is a "systematic assessment of the flows and stocks of materials within a system defined in space and time". It is utilized to connect sources, pathways, and sinks of a material (Brunner and Rechberger, 2004).

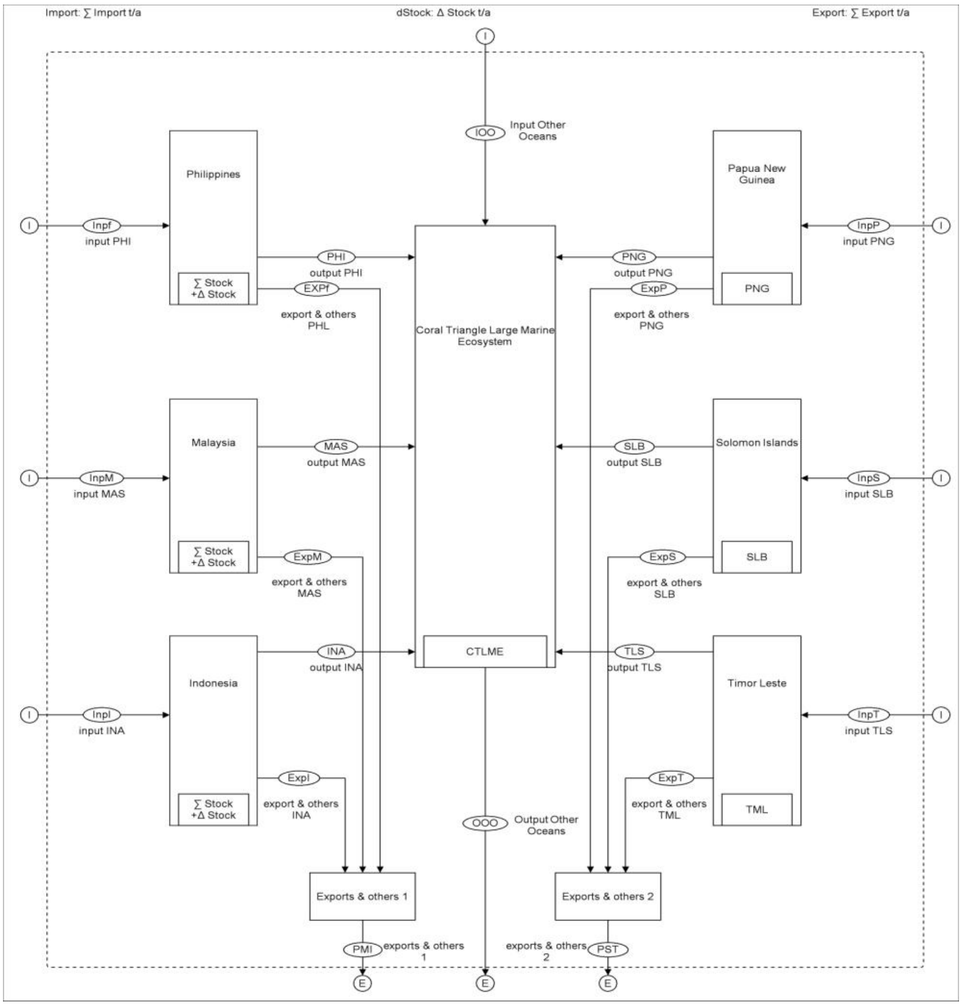
Under the tutelage of Prof. Brunner the researcher learned the rudiments of this methodology. In this research, substances are further distinguished from a bigger classification of materials. Particularly N and P are the elements or substances that this study will delve into. Hence it is but proper to call the methodology a Substance Flow Analysis or SFA.

Brunner and Rechberger describe an MFA or an SFA to possess certain elements the first of which is a "process". A "process" may be the storage, transport, or transformation of materials or substances. The next element of this methodology is a "stock". A stock is measured in mass units and is a reservoir of a particular substance or material. There are also flows that are defined as the mass of the substances or materials per time. These can be "input flows" or "output flows". All these elements make up a system, and this system is defined by a boundary or limit (Brunner and Rechberger, 2004). Particularly the STAN Program developed by the Institute for Water Quality, Waste, and Resource Management of the Technical University will be used to plot figures and perform computations in the SFA.

The Coral Triangle SFA

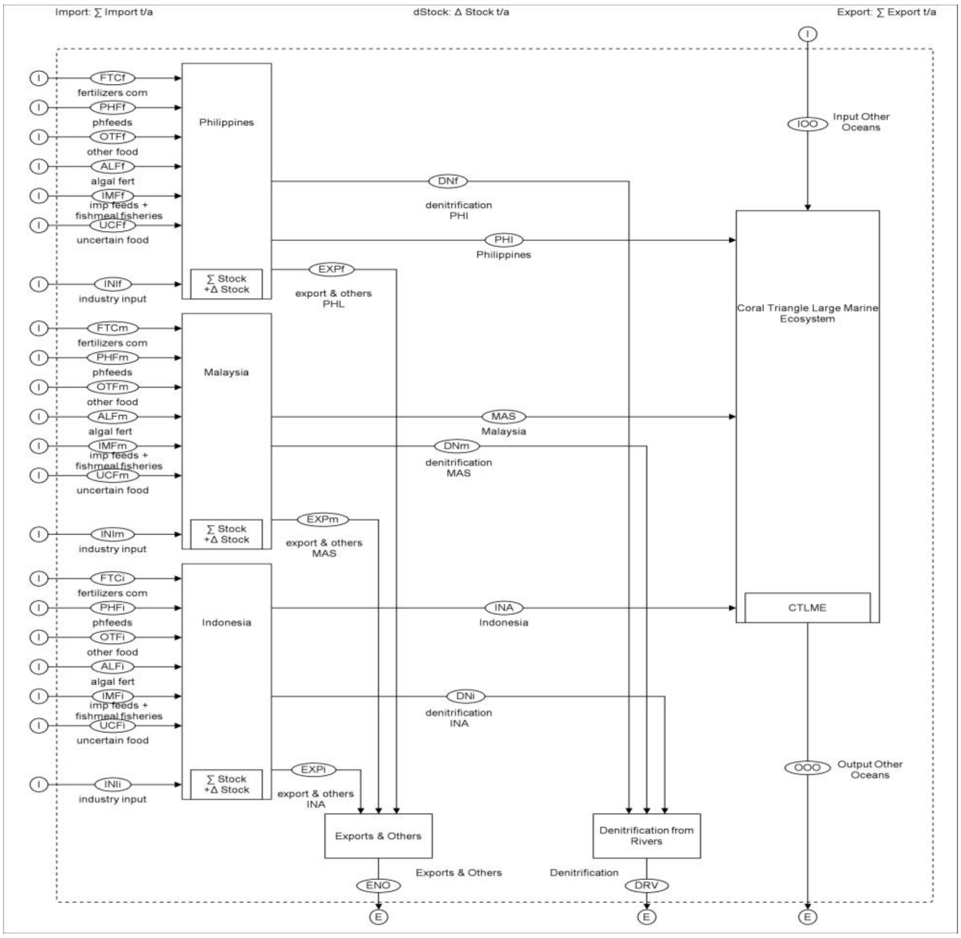
Culling from the concept of an SFA, the researcher has come up with her SFA system for the Coral Triangle. This system consists of the processes representing the countries within the triangle: *The Philippines (PHI), Indonesia (INA), Malaysia (MAS), Papua New Guinea (PN*F), *Solomon Islands (SLB)* and *Timor Leste (TLE*). These countries have input flows to the *Coral Triangle Marine Ecosystem (CTLME).*

Figure 2. The Coral Triangle SFA



In this study the researcher will be assuming that other than the input flows from the countries, all other input flows of N and P to the CTLME amount to zero. However, for this study only the flows from the Philippines, Indonesia and Malaysia will be tackled. A further study can further explore the N and P pathways and inventories of the other island countries. The produce exported by each country goes into the processes *Export 1* (The Philippines, Indonesia and Malaysia). While *Export 2* are for the countries not initially included in the N and P inventories (Papua New Guinea, Solomon Islands and Timor Leste) and hence will be pegged at zero. The output flows from these export processes leave the system. Output flow from the Coral Triangle other than those from exports will also be zero.

Figure 3: Coral Triangle N Overview

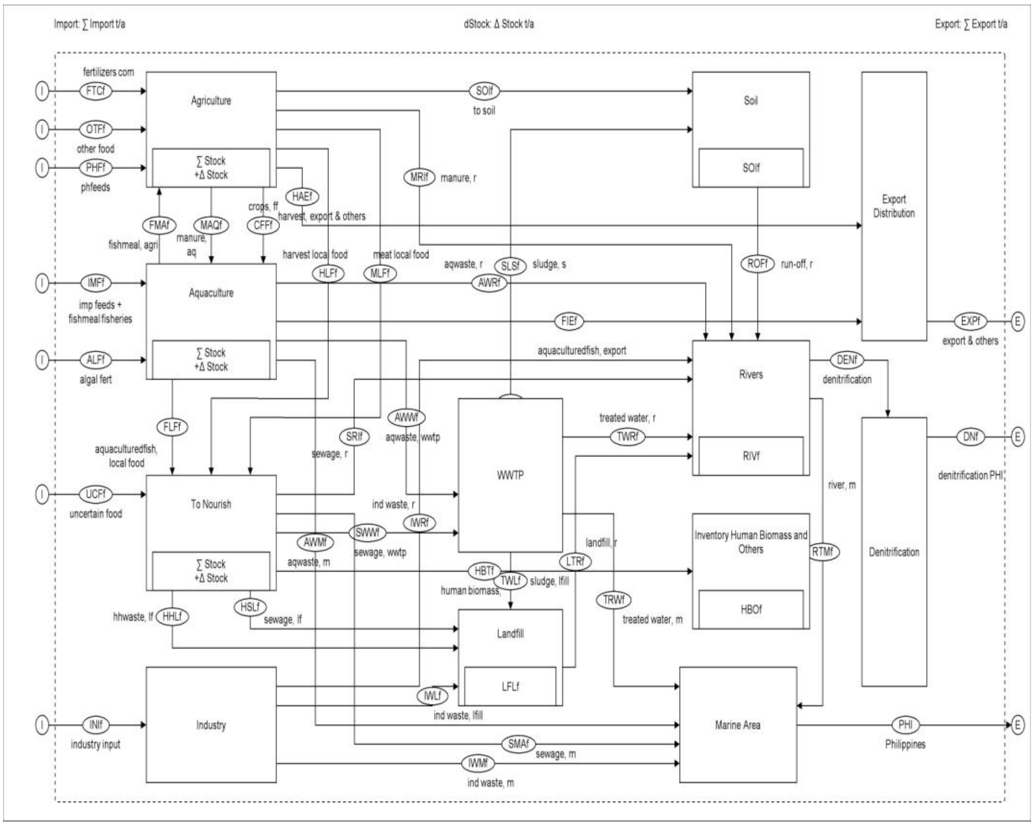


Subsequently, each country is a sub-system within the above bigger system. Hence in Figure 4 there are several inputs in each of the country processes. Their output flows in turn become the inputs into the CTLME. All inflows and outflows in this study represent the N percentages multiplied by the original mass of a material. Hence the values transferred are actually the total mass of N and hence called a substance flow analysis. A similar SFA for P has also been done except the process on denitrification is not included. Furthermore, an additional input flow per *Country Sub-system* in the *P SFA* will be added. This flow is *P detergent*, the mass of P found in surfactants of detergents used in Southeast Asia. This will be further discussed in the P section of the results.

In the following section a flowchart of each country as a sub-system of Figure 4 has been created.

Country Sub-systems

Figure 4. N Country Sub-system



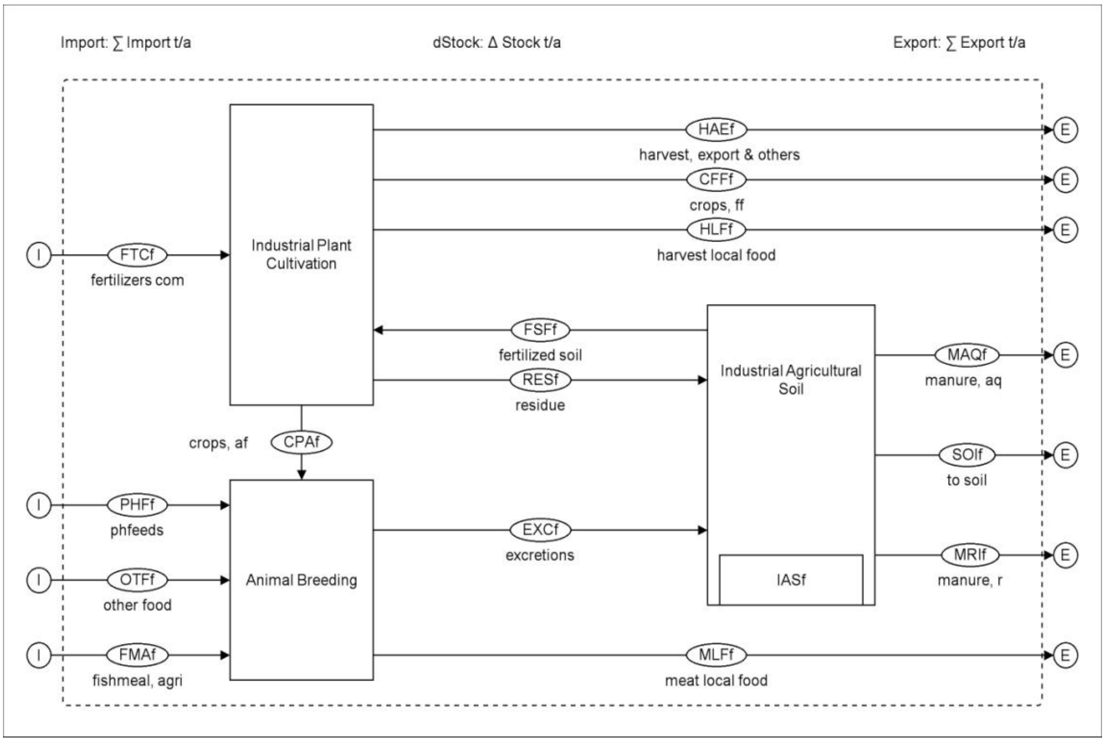
In this sub-system a number of processes are again identified. The processes on the left side consist of livelihood sectors and households in each country. These are *Agriculture, Aquaculture, To Nourish,* and *Industry*. In this study agriculture and aquaculture will be the main focus, as the countries within this region are reliant on these sectors, as well they can be significant sources of N and P. Furthermore *To Nourish* does not only account for the N and P in households but the N and P from food industry and commerce.

In the middle of this sub-system are processes that describe how wastes in these countries are or will be treated. These are *Landfill* and *WWTP* (*waste water treatment plants)*. Although wastewater treatment plants are not commonplace in this region, the researcher included it in the system to evaluate its efficacy as a possible intervention to halt or minimize pollution.

On the right side of the flow chart, one sees processes that are sinks in nature. Sinks are areas wherein substances remain for a certain period of time. Substances may stay in a sink permanently and hence this particular sink can be called a final sink, or they may stay in a sink only for a certain time until they are moved into other sinks or their final sinks. It may also be that a portion of a substance remains in a sink and can be called a stock. These natural sinks are the *Soil, Rivers,* and *Marine Area.* Consequently, all N and P flows come out of each country's *Marine Area* process and go directly to the CTLME. One process along with these sinks is *Inventory of Human Biomass and Others.* This process will account for all N and P in human beings, transpired and respired N and P besides those that go to waste. On the extreme right portion of the *Country Sub-system* there is a process *Export Distribution.* This accounts for all the N and P exported from the country to other areas. In the case of Indonesia and Malaysia this will also account for the N and P of goods exported from East Indonesia to the rest of Indonesia and other countries, as well as those exported by Sabah to the rest of Malaysia. The substances also include the N and P from industrial crops such as rubber, palm oil and the like not transferred to the process *To Nourish.* In Figure 5 the process *Denitrification* is also present. This will not be included in the *P SFA* for each country.

Agriculture Sub-system

Figure 5. Agriculture Sub-system



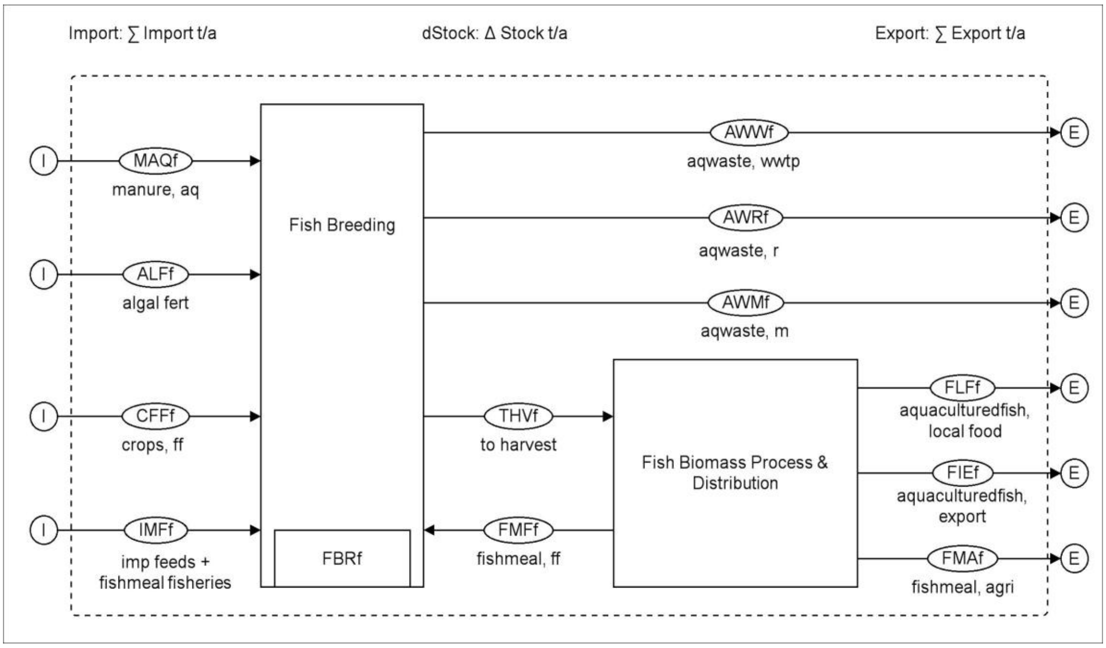
In this study agriculture is sub-divided into two subsectors: the raising of crops and then the raising of animals. The first process represents the former and is labeled *Industrial Plant Cultivation.* These are the areas where crops are planted. Commercial fertilizers are labeled as *fertilizers com.* In this study, N and P are treated in separate systems such that their particular percentages in a particular fertilizer are determined.

The outflows then go on to out of the system in the form of harvests: *harvests, export and others; harvests, local food;* and *crops, ff* (crops going to fish feeds). An output flow *residue* goes to the process *Agricultural Soil.* Nevertheless, an input flow comes back to *Plant Cultivation* in the form of fertilized soil from manure and other biomass.

The second process in Figure 6 is *Animal Breeding.* This process represents the animal husbandry sector of a certain country. There are three inputs from animal breeding: commercial feeds for the animals represented by *phfeeds* (poultry and hog feeds); *other food*, the fodder of all cows and buffalos; and *fishmeal, agri* an outflow from another sub-system *Aquaculture*. Finally, the output of Animal Breeding is *local meat* and *excretions*. *Local meat* re-enters the *To Nourish* sub-system while *excretions* leave the process Agricultural Soil as *manure, r* (manure to rivers), *manure, aq* (manure to marine areas), and *to soil* (nutrients that leave the industrial agricultural soil to go into the *Soil* sub-system or the other areas of soil in the country). These three are input flows to other sub-systems in the CTLME.

Aquaculture Sub-system

Figure 6. Aquaculture Sub-system



Because the Coral Triangle has been a source of seafood, countries in this region have been relying on the sea for their protein needs. This has long been the reason why marine and river environments have been simulated in otherwise terrestrial environments to mimic an ecosystem that produces fish. Nonetheless, most of these operations are monoculture and do not accurately mirror natural ecosystems

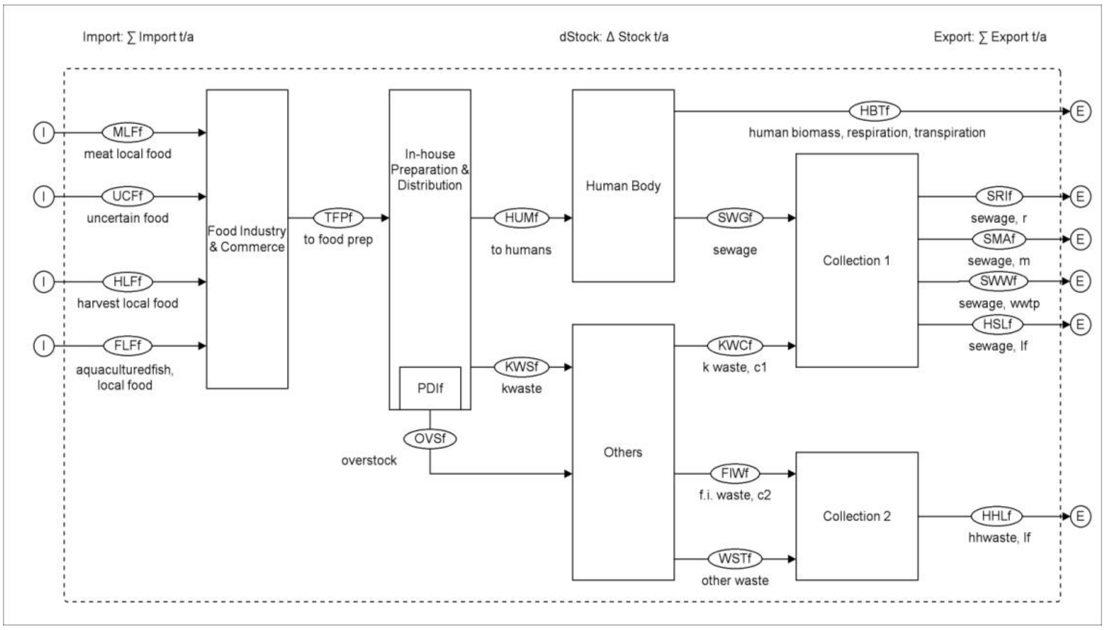
Aquaculture has three processes, the first one of which is labeled *Fish Breeding*. These are fishponds, estuaries or at time fish cages on the coast where fish or crustaceans are raised. There are four input flows to this process. The first one is labeled *manure, aqua* that is also an output flow in the sub-system *Agriculture*. Animal manure is used to stimulate growth of algae for the fish to eat. The next represents commercial algal fertilizers labeled as *algal fert*. They perform the same purpose as commercial algal fertilizers to induce algal growth. For the purposes of this study, the researcher is lumping these substances with the substances from the feeds directly eaten by the fish. More often than not, algal fertilizers and manure are applied into the aquaculture areas, the algae grow and then the fish fry introduced for growth and fattening. Residual substances in the water are ingested by fish, may they be fertilizer residues, algal biomass and their corresponding decomposed state. In the researcher's home province in the Philippines the first algal bloom after the introduction of chicken manure is prized for its fattening properties. Milkfish (*Chanos chanos*) is prized for its thick fat belly, the province's version of foie gras.

Aside from substances to induce algal growth, there are also inputs of fish feeds. These are often used to fatten the fish during the last period before harvesting or are used in semi-intensive or intensive aquaculture where there is an increase in the quantity of raised fish or crustacean in a limited amount of area. Again as in the other systems and sub-systems N and P will be treated separately. The input flow *crops, ff* represents the N and P in local crops used as ingredients for fish feeds. Then there are *imp feeds* + *fishmeal fisheries* which stand for the input flow from imported materials for fish feeds and fish feed coming from sea catch. Some output flows from *Fish Breeding* are residual N and P then transferred on to different processes as inputs in the other sub-systems. These output flows enter waster water treatment plants, rivers and marine areas as outputs. *To harvest* represent the total N or P that is retained in the harvest of aqua-cultured fish. The process *Fish Biomass Process and Distribution* represents the distribution of farm raised fish and crustaceans in a certain country, particularly the N or P from the total mass of the harvest. The output flows from this process are the substances in fish biomass distributed to other sub-systems: *aquaculturedfish, export*; *fishmeal agri* enters *Agriculture* as animal feeds, and *aquaculturedfish, local food* enters *To Nourish*.

There is an output flow from the process *Fish Breeding* becoming an input flow to *Fish Biomass Process and Distribution*. This is *fishmeal, ff* a label for the flow of N or P from aqua-cultured fish converted into fishmeal, and finding its way back as an ingredient for fish feeds.

To Nourish Sub-system

Figure 7. To Nourish Sub-system



Households make up the bulk where people go about their daily activities of nourishing and cleaning. Nonetheless, for this sub-system the researcher accounted for the food industry, as there are also related wastes from this process.

For the purposes of this study *To Nourish* has six processes tracing the N and P pathways within this sub-system. The first process is labeled *Food Industry and Commerce* representing food companies that process raw farm products and distribute them to the end users. The input flows to this process are fourfold: *meat local food* (an output flow from *Agriculture*), *uncertain food* (imported food and sea catch which are not accounted for in the other sub-systems), *harvest local food* (plant crops for human consumption and also an output flow from *Agriculture*), and *aquacultured fish local food* (farm-raised fish as an output flow from the sub-system *Aquaculture*).

The second process is labeled *In-house Preparation & Distribution*. This is where food is processed in kitchens before being assimilated in human bodies or before scraps and wastes are discarded. Figure 8 below shows this output flow from the process *In-house Preparation & Distribution* as input flows to either the process *Human Body* or *Others*. The human body will then stock N and P or excrete it as human wastes that go to another process called *Collection 1*. From this process output flows representing the nutrients from sewage are passed on to rivers, marine areas, waster water treatment plants and landfills. For the sub-system on P an additional in-flow will be added to the process *Others*. This encompasses P inputs such as detergents used in households and it then becomes an input flow joining the P from sewage on to *Collection 1*. Kitchen waste represented by *kwaste* enters *Others* also. It exits as two outflows, one goes to *Collection 1* and another goes to *Collection 2* becoming an input flow to the process *Landfill*.

III-Data Acquisition

The purpose of an SFA is an approximate of real-life scenarios from a model conceived by the creator of the SFA. As a preparatory study, it is a very cost-effective way of diagnosing a problem, as all that is needed is a keen understanding of the scenario and the ability to collect reliable data.

It is very important then that the data one uses are accurate. For this study, the researcher is culling most of her data with regards to households and human metabolism from the figures of Ciba Geigy and Baccini and Brunner's "Metabolism of the Anthroposphere." These figures although done in another continent among a different populace as that which inhabit the Coral Triangle, can be taken as an accurate approximate. Human beings have the same basic intake of protein and starches, but only differ in the form of which they consume them.

Further on, the Food Agricultural Office of the United Nations (FAO) and Canadian Agri-Food Trade Service Southeast Asia will be the sources of data with regards to the sub-systems *Aquaculture* and *Agriculture*. Some of FAO's data are from 2001 while those from Canadian Agri–Food are as recent as 2009-2010. One difficulty the researcher has experienced is to retrieve data from the same years. Hence, in this study the data used will have a range between the years 2001-2005. There are instances where in data will be culled from the late 1990's and 2009. It will be indicated and the proper mathematical adjustments will be done to synchronize it with the year 2005.

The figures gathered by the researcher will then be used to come up with inventories of N and P for each of the countries in this study. After which they will be encoded into the STAN system to yield an SFA.

Nevertheless, since they are simply models and estimates they too have limits. The researchers aim then is to make an estimate as accurate as possible to the real scenario.

IV-Country Results

A. The Philippines

The Philippines is an archipelagic country with all its islands lying within the Coral Triangle. It has one of the most extensive coral reefs as well as one of the highest marine biodiversity in the region. Its total reef area amounts to 27,000 sq km. ((Hoegh-Guldberg et. al., 2009).

Figure 8. Map of the Philippines

Source: Wikipedia "Philippines." (Wikipedia, 2012a)

Nevertheless, population growth is steadily increasing owing to a staunchly Catholic society that prohibits the dissemination of contraceptives.

As of 2012 the estimated population of the Philippines is 103,775,002 thereby being the 12th most populous country in the world (CIA Factbook, 2012). The National Census and Statistics Office in the Philippines estimates a population growth rate of 1.95% for the years 2005-2010 (NCSO Philippines, 2012). The country has a total area of 300,000 sq km. (CIA Factbook, 2012).

According to the Asian Development Bank, the per capita GDP of the Philippines is at 1,790 $ in 2009. Its growth rate in 2010 was 7.3% compared to 1.1% in 2009 (ADB, 2012a).

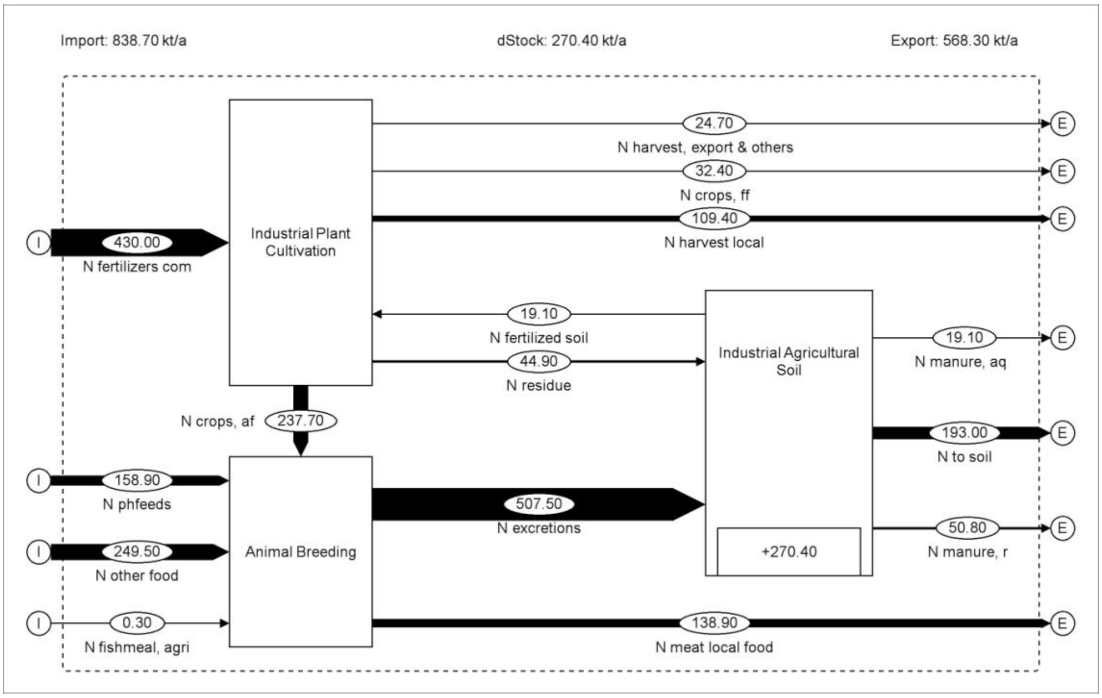
For this study the estimated population for 2005 will be used so as to synchronize with other available data. As of 2005 the population of the Philippines was estimated at 85,261,000 (NCSO Philippines, 2012). The FAO in its estimates for 2005 population makes use of the value 85,500,000 (FAO Agriculture and Consumer Protection, 2006).

The succeeding STAN diagrams will use kilo tons per annum (kt/a).

A.1. Philippines-Nitrogen Sources, Pathways and Sinks

A.1.a. Philippines-Agriculture Nitrogen Sub-system

Figure 9. N Agriculture Sub-system, Philippines (kt/a)



The Philippines is still largely an agricultural country. In this study, the researcher opted to explore both cultivation of crops and animal husbandry into this one sub-system labeled *Agriculture*.

The first process in this sub-system is *Industrial Plant Cultivation*. The input flow that goes into this process is *N Fertilizers Com* representing the Nitrogen content of fertilizers applied in agricultural areas for a given year. For this data, the researcher subscribed to FAO's fertilizer database. The latest results were from 2001 and it denoted that the Philippines has 382,070 tons of N/a from commercial fertilizers applied to the cultivation of crops (FAOSTAT, 2012a). Furthermore, in a paper written by Reyes et. al. for Greenpeace, they attached an FAO graph showing that there was an approximate increase of fertilizer use in the Philippines (Reyes et. al., 2008). The researcher extrapolated from the graph and found an approximate increase of 12% from fertilizer usage in 2001 to 2005. Because the only complete data FAO has on N composition is for 2001, the researcher multiplied 382,000 tons N/a by 12% achieving a value of 427,840 tons/a rounded to 430,000 tons/a as an input of N from commercial fertilizers.

The ouptut flows from *Industrial Pant Cultivation* are five-fold. These four output flows to be discussed are the amounts of Nitrogen that find themselves in crop harvests. These flows are: *N crops, af* (animal feeds); *N crops, ff* (fish feeds); *N residual* (N which is not used up by the plants and is passed on to *Industrial Agricultural Soil)*, *N harvest local* (crops consumed by local populace); *N harvest export and others* (crops exported to other countries and industrial crops). All flows add up to Products from Plant Cultivation plus the difference between the input flows to *Industrial Plant Cultivation* and the Products from Plant Cultivation.

Products from Plant Cultivation**=Crq x Ppcp x Npp**

Where:

Crq=quantity of crop harvests per annum

Ppcp= average percentage of crude protein in a basket of crops

Npp=Nitrogen percentage in protein= 0.16 (Craig and Helfrich, 2009)

N Products from Plant Cultivation**=70,174,000 tons/a x 0.04 x 0.16**

=449,113.6 rounded to 449,100 tons/a

The figure for the annual crop harvest was based on adding the crops outlined by FAO statistics for 2005 (FAOSTAT, 2012C). These crops include rice, maize, cassava, bananas, sugar cane, tropical fruits and vegetables and all plant produce. To achieve an average crude protein percentage the researcher culled the following data (Ciba Geigy, Lentner ed., 1981)

"Rice=6.7 g/100 g edible portion

Potato=2.1 g/100 g edible portion

Corn grits=8.8g/100 g edible portion

Bananas=1.1g/100 g edible portion

Mango=0.70g/100 g edible portion

Asparagus=2.1g/100 g edible portion

Eggplant=1.2g/100 g edible portion"

Averaging the above, one gets a value of 3.24% crude protein percentage or .032 which will be the value for *Ppc2* and *Ppc3* in succeeding computations. These are crops used for human consumption. The researcher is then assuming that 90% of crops is used for humans and 5% used for animals and 5% for industrial crops (fibrous crops such as abaca, tobacco, rubber). In the following chapters *Ccp* (see page 29) or crude protein percentage from crops was 42% but these were already processed crops for feeds and hence nutrients are concentrated. Hence a 12% crude protein percentage based on averaging starches from Ciba Geigy will be used. This same 12% or 0.12 will be used in succeeding computations as the value of *Ppc1*.

(12 x 0.05)=0.6

(3.24 x 0.95)=3.078

The sum of the above products is 3.678 % rounded to 4% representing a crude protein percentage for the basket of crops produced in the Philippines for 2005.

After culling the crude protein percentage or *Ppc* it is then multiplied by 16%. Proteins are made of 50% Carbon, 16% Nitrogen, 21.5% Oxygen and 6.5% Hydrogen (Craig and Helfrich, 2009).

There is also part of crops that are used as animal feeds and hence is an input to *Animal Breeding*. For this flow the researcher is using data culled from a report of the Canadian Agri-Food Trade Service, particularly the values for *Cap, Pcp* and *Hcp* (Canadian Agri-Food Trade Service, 2009a). The following formula is used:

N Crops, af **={(Afq x Cap) x (Pcp + Hcp) x Cpp x Npp}**

Where:

Afq=quantity of total animal feeds

Cap=percentage of total animal feeds from local crops

Pcp=percentage of local crops that goes into poultry feeds

Hcp=percentage of local crops that goes into hog feeds

Ccp=crude protein percentage in crops

(See page 29 for a detailed computation of this *Ccp*)

Npp=percentage of N in protein

N Crops, af **=(6,000,000 tons/a x 0.67) x (0.55 + 0.33) x 0.42 x 0.16}**

=237, 726.72 rounded to 237,700 tons/a

The researcher also assumed a value of 10% of the Products of Plant Cultivation such as rice stalks, and other plant material left on the fields and used as an organic fertilizer. This 10% along with the difference between inflows to Industrial Plant Cultivation and Products of Plant Cultivation make up the flow *N residue*.

The Department of Science and Technology in the Philippines has started to promote the use of organic fertilizers. The Philippines, although it is an agricultural economy uses only a small portion of its organic waste resources (Canadian Agri-Food Trade Service, 2009a).

The Philippines to some extent also exports coconuts, bananas, and other tropical fruits and vegetables. In the Country Report of FAO on the State of Plant Genetic Resources for Food And Agriculture, the Philippines has an export value of 2.7% of total production of its major crops (Altoveros and Borromeo, 2007). Furthermore, the percentage for total local industrial crops was derived by dividing the number of tons for harvested industrial crops such as coconut crude oil in the FAO study done by Altoveros and Borromeo over the total tons of harvest. This is estimated at 2.8% of total crop production.

To Local Industrial Crops= 449,100 x 0.028=12,574.8 rounded to 12,600 tons/annum

N harvest export=449,100 x 0.027=12,125.7 rounded to 12,100 tons/annum

***N harvest export and others*= Total Local Industrial Crops + N harvest export =24,700 tons/a**

The STAN program then automatically computes for *N harvest, local food* also an input flow to the *To Nourish* sub-system

A percentage of the crops are also used as ingredients for fish feeds. This is computed in the following *Aquaculture* sub-system and is represented by the flow *N crops, ff.*

Animal Breeding has the following input flows: *N crops af* (crops to animal feed), *N phfeeds* (imported pig and hog feeds and fishmeal from local sea catch), *N fishmeal, agri* (fishmeal from local farm-raised fish), and *N other food. N other food* accounts for the nitrogen in grass and other plants in the environment such as wild swamp cabbage not included in *N, crops af.* These are fed mostly to cattle, buffalo, hogs in the Philippines. It also accounts for fishmeal from trash fish which is a by-product of sea caught fish, not included in the *Aquaculture* SFA. It may also account for any N in feeds which is not taken into account in the Canadian Agri-Food Trade Service study.

N, fishmeal agri is computed for in the *Aquaculture* sub-system discussed in the following chapter. The other input flow is poultry and hog feeds from imported crops and fishmeal plus fishmeal from local sources other than aquaculture. This flow is labeled as *N, Phfeeds*. The researcher found data on poultry and hog feeds for the year 2009 (Canadian Agri-Food Trade Service, 2009a). The following values below are culled from the Canadian Agri-Food Trade Service Study. To compute for this inflow of feeds, the researcher has this formula:

***N, Phfeeds*= {(Icq x Ppz) x (Pip + Hip) x Ccp x Npp} + {(Icq x Pfp) x (Pip +Hip) x Npp}**

Where:

Icq=quantity of imported commercial feed ingredients

Ppz=percentage of plant material from these feed ingredients

Pfp=percentage of fish meal from these feed ingredients

Pip=percentage of imported ingredients that go to poultry feeds

Hip=percentage of imported ingredients that go to hog feeds

Cip=crude protein percentage from imported crop materials

Npp= N percentage of protein

Pfp=percentage of imported fishmeal in commercial animal feeds

Cmp=crude protein percentage from imported fishmeal

Fla= Fishmeal from local fisheries to animal breeding

{(Icq x Ppz) x (Pip + Hip) x Ccp x Npp}={(2,000,000 tons/a x 0.13) x (0.55 +0.33) x 0.42 x 0.16}=15,375.36 rounded to 15,400 tons/a

{(Icq x Pfp) x (Pip +Hip) x Cmp x Npp}={(2,000,000 tons/a x 0.67) x (0.55 +0.33) x 0.725 x 0.16}= 136,787.2 rounded to 136,800 tons/a

Fla=6,653.5 rounded to 6,700 tons/a (See page 33 for the computations of this value)

***N, Phfeeds*= 15,400 tons/a + 136,800 tons/a +6,700 tons/a=158,900 tons/a**

The output flow from *Animal Breeding* is *N, excretions*. There are several ways to compute for this. In this study the researcher, based on the data she found, used the following formula:

N, excretions=∑ animal heads per year x N excretion per animal per year

N, excretions=(Phq x Nep) + (Hhq x Neh) + (Rhq x Ner)

Where:

Phq=number of poultry (chicken) heads per annum

Nep=N excretion in kg per chicken per year

Hhq=number of pig heads per annum

Neh=N excretion in kg per pig per year

Rhq=number of cows and buffalo per annum

Ner=N excretion in kg per ruminant per year

***N, excretions*= (Phq x Nep) + (Hhq x Neh) + (Rhq +Ner)**

***N, excretions*=(136,000,000 x 0.52 kg) + (12,140,000 x 10.3 kg) + {(2,489,000 +3,327,000) x 53.6 kg}**

***N, excretions* =507,499,600 kg/a rounded to 507,500 tons/a**

The values for the number of heads for poultry, hogs, cattle and buffalo were based on a report of the Canadian Agri-Food Trade Service. These values on Philippine animal production are based on 2005 figures (Canadian Agri-Food Trade Service, 2009a). In Austria's Informative Report for 2008 on Agriculture, chicken has an estimated excretion of 0.52 kg of N per animal per year (Anderl, et. al., 2008). This is the same value the researcher is using for *Nep* in this paper. Fattening pigs are at 10.3 kg of N per animal while cattle 1-2 years is pegged at 53.6 kg of N per animal per year (Anderl, et. al., 2008). The value for fattening pigs represent *Neh* in this study, while the value for cattle represent *Ner*.

For the N remaining in animal meat, the researcher is basing her figures on an interview with Professor Matthias Zessner of the TU Wien who has worked on nutrient loads in the Danube. In the interview Prof. Zessner approximated that, of 100% N intake, 30% goes to pork and chicken meat while 70% goes to excretion. For beef, 15% remain with the product, while 85% goes to excretion (Zessner, 2012). The researcher then derived the N that goes to the finish product such as meat, eggs, dairy products labeled *N meat local food*.

***N meat local food*=∑ N in poultry produce + N in pork produce + N in cattle and buffalo**

N in poultry produce={(Phq x Nep)/0.70} x 0.30

={(136,000,000 x 0.52 kg)/0.70} x 0.30=30,308.57 rounded to 30,300 tons/a

N in pork produce={(Hhq xNeh)/0.70} x 0.30

={(12,140,000 x 10.3 kg)/0.70} x 0.30=53,589.32 rounded to 53,600 tons/a

N in cattle and buffalo={(Rhq +Ner)/0.85} x 0.15

{(2,489,000 +3,327,000) x 53.6 kg}/.85 x 0.15=55,012.51 rounded to 55,000 tons/a

***N meat local food*=138,900 tons/a**

The IPCC Guidelines have a similar value for retention rates as Prof Zessner's value except with regards to buffalo and other cattle wherein the IPCC details it to be 0.07 percent (IPCC, 2006). The researcher then assumes that 0.93 goes to excretion. Another version of the computation below:

***N meat local food* =∑ N in poultry produce + N in pork produce + N in cattle and buffalo**

N in poultry produce={(Phq x Nep)/0.70} x 0.30

={(136,000,000 x 0.52 kg)/0.70} x 0.30=30,308.57 rounded to 30,300 tons/a

N in pork produce={(Hhq xNeh)/0.70} x 0.30

={(12,140,000 x 10.3 kg)/0.70} x 0.30=53,589.32 rounded to 53,600 tons/a

N in cattle and buffalo={(Rhq +Ner)/0.93} x 0.07

{(2,489,000 +3,327,000) x 53.6 kg}/0.93 x 0.07=23,464.12 rounded to 23,500 tons/a

***N meat local food* =107,400 tons/a**

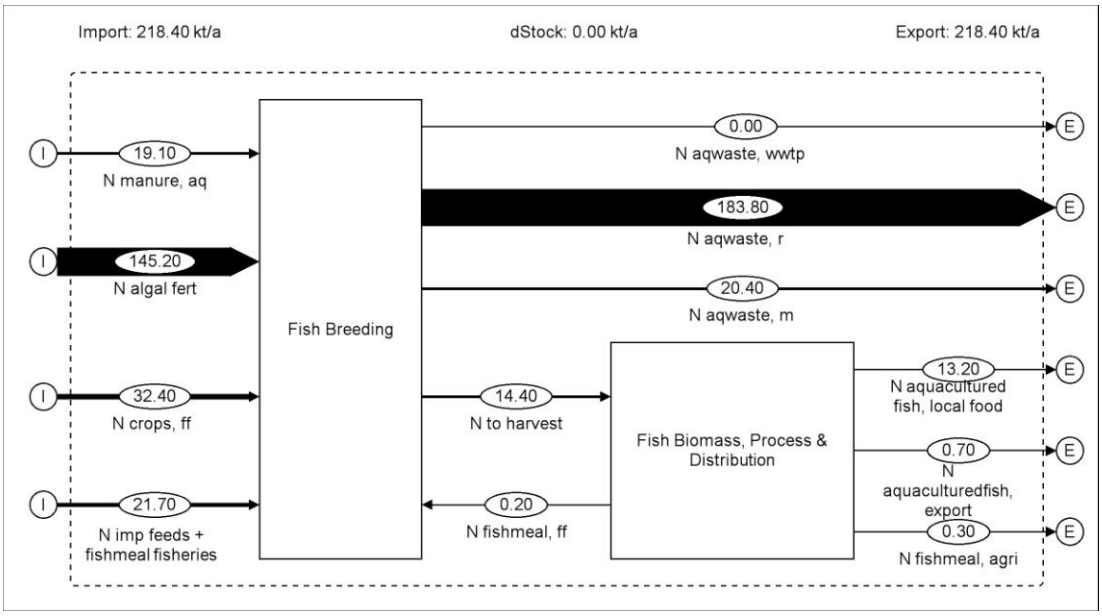
There is a difference of 31,500 tons between the two computations. As the researcher has no values for other animal products such as eggs, butter and milk produced, she will just take the higher value to compensate for the lack of figures for eggs and dairy products.

The difference between the inputs to *Animal Breeding* and *N excretions* is the N in meat. For this systems model, the assumption is that they all go to local food since the Philippines is not a big meat producer and has no significant meat exports. This outflow *N, meat local food* also includes other products such as eggs and dairy; dairy being produced in very small quantities as most of the dairy products are imported from either New Zealand or Australia.

Finally, the last process is *Agriculture Soil.* This process has two input flows. *N residue* is the difference between all the inputs to *Plant Cultivation* and the harvests. This will indicate whether there is excess fertilization or not. *N excretions* also go to *Agricultural Soil* and are further distributed to the aquaculture sub-system as *N manure, aq* or to the process *Rivers* as *N manure, r. N, manure aq* is also computed in the following chapter on *Agriculture*. *N manure r* is computed by subtracting *N, manure aq* from *N, excretions*. Whatever is N left in *Industrial Agricultural Soil* and which is not passed on to *Industrial Plant Cultivation* as N fertilized soil becomes in output flow from this process but enters as an input flow to the larger process *Soil* in the environment.

A.1.b Philippines-Aquaculture Nitrogen Sub-system

Figure 10. N Aquaculture Sub-system, Philippines (kt/a)



The process *Fish Breeding* has four input flows. The first input flow is labeled *N manure, aq* and this input flow is an output flow from the sub-system *Agriculture.*

According to a FAO Fisheries Technical Paper, most of the manure used as fertilizers for aquaculture is chicken manure while hog cow and buffalo manure account for a smaller percentage (Sumasgaysay-Chavoso, 2007). The researcher is using the value of N in poultry manure 3.9% of the mass of manure (Mitchel, et. al.).

***N manure, aq*= M x MaN**

Where:

M=amount of chicken manure from domesticated animals used by the aquaculture industry in tons/year.

MaN= percentage of N in a particular animal manure used in the aquaculture industry

***N Manure, aq*=489,998 tons x .039=19,109.92 rounded to 19,100 tons/a**

The next input flow would be commercial algal fertilizers labeled as the flow *N algal fert.* Aside from manure, fish farmers use commercial fertilizers to stimulate algal growth. Commercial algal fertilizers amounted to 869,513 tons for the year 2004. Most of these fertilizers consist of the following: Urea (172,333 tons), Ammonium Sulphate (86,568 tons), Monoammonium Phosphate (158,666 tons), Diammonium Phosphate (18,087 tons), 14-14-14 NPK (286,946 tons) totaling a sale of 569,513 tons of commercial algal fertilizers in the Philippines for the year 2004 (Sumagaysay-Chavoso, 2007). To derive the N content of these fertilizers, one has to know their stoichiometry and molecular mass derived from a periodic table. The following are computations on how the percentage of N is derived:

i. Urea $CO(NH_2)_2$

C= 1 x 12.011 grams/mole=12.011 g/mol

O=1 x 15.999 g/mol=15.999 g/mol

N=2 x 14.007 g/mol=28.014 g/mol

H=4 x 1.0079 g/mol=4.0316 g/mol

The numbers on the left side represent the stoichiometry of the substance or element and the number on the right represent the atomic mass. To derive the molecular mass of the whole compound, one has to add the atomic mass of all the substances.

Molecular mass of $CO(NH_2)_2$= 60.0556 g/mol

To determine the percentage of N one has to divide the atomic mass of N in the compound over the molecular mass of Urea. Doing so this is achieved:

Proportion of N in Urea= 28.014 g/mol /60.0556 g/mol=0.4665 of 46.7%

To determine the amount of Urea used in the Philippines for the year 2004, simply multiply the Proportion of N in Urea by the amount of Urea consumed during that period:

N in Urea= 0.467 x 172,333 tons/a=80,479.511 rounded to 80,500 tons/a.

The succeeding compounds will be computed based on the method of determining N in Urea.

ii. Ammonium Sulphate $(NH_4)_2SO_4$

N=2 x 14.007=28.014

H=8 x 1.0079=8.0632

S=1 x 32.065=32.065

O=4 x 15.999=63.996

Molecular mass of $(NH_4)_2SO_4$=132.1382 g/mol

Proportion of N in Ammonium Sulphate=28.014 g/mol/132.1382g/mol =0.2120 or 21.2%

N in Ammonium Sulphate, 2004=0.212 x 86,568 tons=18,352.87564 or 18,400 tons/a

iii. Monoammonium Phosphate $(NH_4)H_2PO_4$

N=1 x 14.007=14.007

H=6 x 1.0079=6.0474

P=1 x 30.974=30.974

O=4 x 15.999=63.996

Molecular mass of $(NH_4)_3PO_4$ =115.0244 g/mol

Proportion of N in Monoammonium Phosphate=14.007/mol/115.0244 g/mol

=0.1217 or 12.2%

N in Monoammonium Phosphate=0.120 x 158,666 tons/a

=2,284.7904 rounded to 2,300 tons/a

iv. Diammonium Phosphate $(NH_4)_2HPO_4$

N=14.007 x 2=28.014

H=9 x 1.0079=9.0711

P=1 x 30.974=30.974

O=4 x 15.999=63.996

Molecular mass of $(NH_4)_2HPO_4$=132.0551 g/mol

Proportion of N in Diammonium Phosphate=28.014g/mol/132.0551g/mol

=0.2121 or 21.2%

N in Diammonium Phosphate= 0.2120 x 18,087 tons/a=3834.444 or 3800 tons/a

The last fertilizer most commonly used is NPK, also called 14-14-14 (Sumagaysay-Chavoso, 2007). This is 14% each of Nitrogen, Phosphate (P_2O_5) and Potash (K_2O) the most common forms of substance and compounds in fertilizer studies. The N percentage is simply computed by multiplying 14% by the quantity in tons of NPK for the year 2004:

v. N in NPK- 0.14 x 286,946 tons/a=40,172.44 or 40,200 tons/a

To determine the total N in algal fertilizers consumed in 2004, the total N for each of the fertilizer types are simply added:

***N algal fert*= ∑ N in Fertilizers**

N algal fert=80,500 tons/a + 18,400 tons/a + 2,300 tons/a + 3800 tons/a + 40,200 tons/a

= **145,200 tons/a**

The third input flow is *N crops, ff.* In a 2009 report of the Canadian Agri-Food Trade Service Southeast Asia, the total demand of animal feed is estimated at 8,000,000 tons per annum of which 6,000,000 tons come from agricultural products and wastes from domestic production. The following is a breakdown of the types of agricultural products used in animal feeds from local ingredients: starchy roots (2%), rice (9%), corn (54%), vegetable and fruit material (20%), fishmeal (13%), other products (2%).

Twelve percent (12%) of these items go to the manufacture of fish feeds for aquaculture (Canadian Agri-Food Trade Service, 2009a). For the purpose of computations, the researcher is taking into account first all plant materials garnering a share of 67%. The other products, because they are unknown will not be taken into account in the computations. These plant materials are pegged at an average of 42% crude protein averaging the said percentages of respective crop feeds in aquaculture from FAO. FAO reports on some plant material for fish feeds culled from SEAFDEC data. The researcher averaged the following crude protein percentages: Soybean meal 68.4%, Corn gluten 62.83%, Sweet potato leaf meal 29.18%, Cassava leaf meal 27.56%, Copra meal 20.32% garnering a mean crude percentage of 42% (Piedad-Pascual, 1993). They are then multiplied by 16%. Proteins are made of 50% Carbon, 16% Nitrogen, 21.5% Oxygen and 6.5% Hydrogen (Craig and Helfrich, 2009).

***N crops, ff*= (Dcf xFp) x Aqp x Ccp x Npp**

Where:

Dcf=domestic crop for feeds

Fp=percentage of feeds from plants

Aqp=percentage of feeds that go to aquaculture

Ccp=crude protein percentage from said crops

Npp=N percentage in protein

***N crops,ff*= (6,000,000 tons/a x 0.67) 0.12 x 0.42 x 0.16**

=32,417.28 rounded to 32,400 tons/a

This is also the output flow from the process *Plant Cultivation* in the succeeding *Agriculture* sub-system.

In this sub-system N *imp feeds + fishmeal fisheries* will stand for the total amount of imported prepared feeds and commercial feeds manufactured from imported crops and imported fish meal plus fishmeal from local sea catch, meaning wild caught trash fish. The following is the formula that the researcher came up with to derive the amount of N *imp feeds +fishmeal fisheries*:

***N imp feeds + fishmeal fisheries*= (Imf x Pfp x Cfp x Npp) + (Imf x Icp x Aqp x Cip x Npp) + (Imf x Mfp x Aqp x Cmp x Npp) + Flf**

Where:

Imf=quantity of imported fish feeds

Pfp=percentage of prepared fish feeds

Cfp=crude protein percentage from prepared fish feeds

Npp=N percentage in protein

Icp=percentage of imported crop material in Imf

Aqp=percentage going to aquaculture instead of other animal feeds

Cip=crude protein percentage from imported crop materials

Mfp=percentage of imported fish meal material in Imf

Cmp= crude protein percentage from imported fishmeal material.

Flf= fishmeal from local fisheries to aquaculture

Taking the same proportion as in the domestic feed structure, we are assuming the following percentages from each category make up the same as imported materials. For example Icp is 0.67 while Mfp is 0.13. The prepared foods percentage is culled from the percentage "other products" of 2% (Canadian Agri-Food Trade Service, 2009a). Furthermore the crude protein percentage from prepared fish feeds or Cfp is taken from the Virginia Tech Report by Craig et. al.. Here the researcher averaged the following percentage of protein from prepared feeds: 18-20% marine shrimp feeds (18-20%), catfish feeds (28-32%), tilapia feeds (32-38%), hybrid striped bass feeds (38-42%), (Piedad-Pascual, 1993) arriving at an estimated crude protein percentage of 40%. At the same time, Cmp was derived by averaging the crude protein percentage of different types of fish meal used for aquaculture: white fish meal (70.50%), Peruvian fish meal (70.51%), slipmouth fishmeal (65.95%), tuna fish meal (77.23%) and herring fish meal (78.40%) (Piedad-Pascual, 1993) yielding a mean crude protein percentage of 72.5%.

Imf x Pfp x Cfp x Npp=2,000,000 tons/a x 0.02 x 0.40 x 0.16

=2,560 rounded to 2,600 tons/a

Imf x Icp x Aqp x Cip x Npp= 2,000,000 tons/a x 0.67 x 0.12 x 0.42 x 0.16

=10,805.76 rounded to 10,800 tons/a

Imf x Mfp x Aqp x Cmp x Npp= 2,000,000 tons/a x 0.13 x 0.12 x 0.725 x 0.16

=3,619.2 rounded to 3,600 tons/a

Flf=4,694 rounded to 4,700 tons (See page 32 for computations of this value)

***N imp feeds + fish meal fisheries*= 2,600 tons/a +10,800 tons/a + 3,600 tons/a+ 4,700 tons/a=17,000 tons/a**.

From the process *Aquaculture Areas*, there is an output flow that becomes an input flow to the process *Fish Biomass, Process and Distribution*. This flow is labeled *N to harvests*, and represents the amount of N of fish intake. The FAO reports a total of 481,266 tons of fish and crustaceans from aquaculture produced in 2004, excluding mariculture or raising of seaweed that amounted to 1,235,761 tons (Sumagaysay-

Chavoso, 2007). Nevertheless, this study will tackle simply fish and crustaceans as seaweed production are normally done in the sea with minimal N and P inputs in terms of fertilizers and feeds. Hence, the researcher will use the value 481,000 tons/a as total aquaculture harvest per annum

In a study done by Dr. Cuvin-Aralar she detailed that the optimum intake of protein for Nile tilapia (Oreochromis niloticus) at 24 degrees Celsius is 24%. Increase in protein percentage does not alter the weight of the fish (Cuvin-Aralar, 2003). The Nile tilapia, also called Nilotica in the researcher's native language is a very common aqua-cultured fish in the Southeast Asia. It is raised in both fresh and brackish water in Southeast Asia. At the same time in a study comparing crude protein content of fish, it was detailed that an approximate N content of milkfish (Chanos chanos) one of the most common aqua-cultured fish at 100-300 grams is an estimated at 2.6% rounded to 3%. The study further shares that N content differs with the weight of the fish (Ramseyer, 2002). The researcher picked the 100-300 grams weight because this is the most common weight fish farmers grow their fish before they are harvested and sold. Some prawns will have less N percentage as they are grown between 80-100 grams. However, the little difference will make up for some fish wish are grown over the standard 100-300 grams for specialty stores.

To compute for this flow:

***N to harvest*=Sgq x Npf**

Where:

Sfq=quantity of seafood (fish and crustacea) from aquaculture

Npf=N percentage in fish

N to harvest=481,000 x 0.03=14,430 rounded to 14,400 tons/a

N fishmeal, ff is the output flow from *Fish Biomass, Process and Distribution* but an input flow to the first process *Aquaculture Areas*. It is computed by the following formula:

***N fish meal, ff*= {(Afq x Fmp x .05) x Ffp} x Clf x Npp**

Where:

Afq=quantity of animal feeds

Fmp=percentage of total animal feeds from local fish. It is assumed that 5% of total fishmeal percentage of 13% comes from aquaculture.

Ffp=percentage of fish in animal feeds that goes to fish feeds

Clf=crude protein percentage in local fishmeal

Npp=percentage of N in protein

***N fish meal ff*={(6,000,000 tons/a x 0.13 x.05) x 0.12} x 0.33 x 0.16**

=247.104 rounded to 200 tons/a

Fishmeal from local fisheries (wild caught) to aquaculture or **Flf= {(6,000,000 tons/a x 0.13 x.95) x 0.12} x 0.33 x 0.16=4,694 rounded to 4,700 tons,** added to *N imp feeds* flow

The *Clf* value is taken from the FAO study of Abidin Nur. The Philippines like Indonesia prefers to import fishmeal because imported fishmeal has a higher crude protein percentage than local fishmeal. According to Nur, imported fishmeal has a crude protein greater than 65% of the mass of the product. Local fishmeal however has 33-55 % crude protein percentage (Nur, 2007). The researcher opted to use the lower percentage, because local fish was estimated to have 3% N of its total mass. An exception will be for Malaysia whose *Clf* value indicates a higher crude protein percentage. This is further discussed in the Malaysian chapter. The researcher personally views that because the fishing grounds of Sabah, Malaysia are situated in an area where coral reefs are not as blasted as that of the Philippines and Indonesia, their fishmeal from local sea catch comes from bigger fish.

N fishmeal, agri is another outputflow that comes from *Fish Biomass, Process & Distribution*. It is computed as the total share of harvests from aquaculture in the country that end up in animal feeds in agriculture. These feeds are both poultry and hog feeds. To compute for this output flow the following is the formula:

***N fishmeal, agri*={(Afq x Fmp x Paq x.05) x (Pfp + Hfp) x Clf x Npp}**

Where:

Paq=Percentage of local catch of the Philippines that goes to fish meal

Pfp=percentage of local fishmeal that goes into poultry feeds

Hfp=percentage of local fishmeal that goes into hog feeds

In this model, the researcher is assuming that only 5% of the total fishmeal comes from aqua-cultured species. According to FAO 18% of total fish produced in the Philippines come from aquaculture (FAO Fisheries and Aquaculture Dept, 2012a). The rest of *N other food* as an inflow of *Animal Breeding* may consist of fishmeal from fisheries or fish caught from the sea.

***N fishmeal,agri*={(6,000,000 tons/a x 0.138 x 0.18 x 0.05) x (0.55 +0.34) x 0.33 x 0.16}**

=350.18 rounded to 300 tons/a

Fishmeal from local fisheries to animal breeding or **Fla={(6,000,000 tons/a x 0.138 x 0.18 x 0.95) x (0.55 +0.34) x 0.33 x 0.16}=6,653.5 rounded to 6,700 tons/a**

There are no figures as to how much of farm raised fish goes to fishmeal. However, based on the researcher's experience in the aquaculture industry, high value fish for human consumption is raised and only a very small percentage such as trash fish which incidentally grew in the ponds as well as rejects are used to make fishmeal, hence the 5% of total fishmeal from aquaculture as an estimate was made.

According to the FAO, in 2003 fish export from the Philippines accounted for 6.5% of total fish production. That accounts for a production of 2,393,659 tons of fish in live weight, while exports are at 155,129 tons (FAO Fisheries and Aquaculture Dept., 2012b). Nonetheless this FAO data refers to fish caught in the seas. The export percentage however for aqua-cultured fish, most specifically for milkfish is 0.60 % of its production (Castro-Manhart, 2006). On the other hand, prawn exports as of 2005 were said to have doubled and reached 18,101 tons (TheFishSite, 2007). So with the researcher's data of 481,000 tons of aquaculture produce, prawns export make up approximately 4%. Adding the two values will yield 4.6%. Hence, the researcher will assume a 5% of total aquaculture for export

***N fish export*= *N to harvest* x 0.05**

=14,400 tons/a x0.05=720 rounded to 700 tons/a

N fish, local food is then automatically computed by the STAN program.

N fish excr is an outputflow from the process *Fish Biomass, Process & Distribution*. To compute for this the researcher is culling data from a study by Lazzari and Baldiseratto where 51kg of N per 1000kg of fish is excreted, making it 5.1% (Lazzari and Baldisseratto, 2008). In addition, most nitrogen in the excretion of fish consists of ammonia which come out of the gills while 10% are solid wastes (Craig and Helfrich, 2009).

***N fish excretions*=Sfq x Enf**

Where:

Sfq=quantity of seafood (fish and crustacea) from aquaculture

Enf=percentage of N excretion for every ton of fish

***N fish excretions*= 481,000 tons/a x .051 =24,531 or 24,500 tons/a**

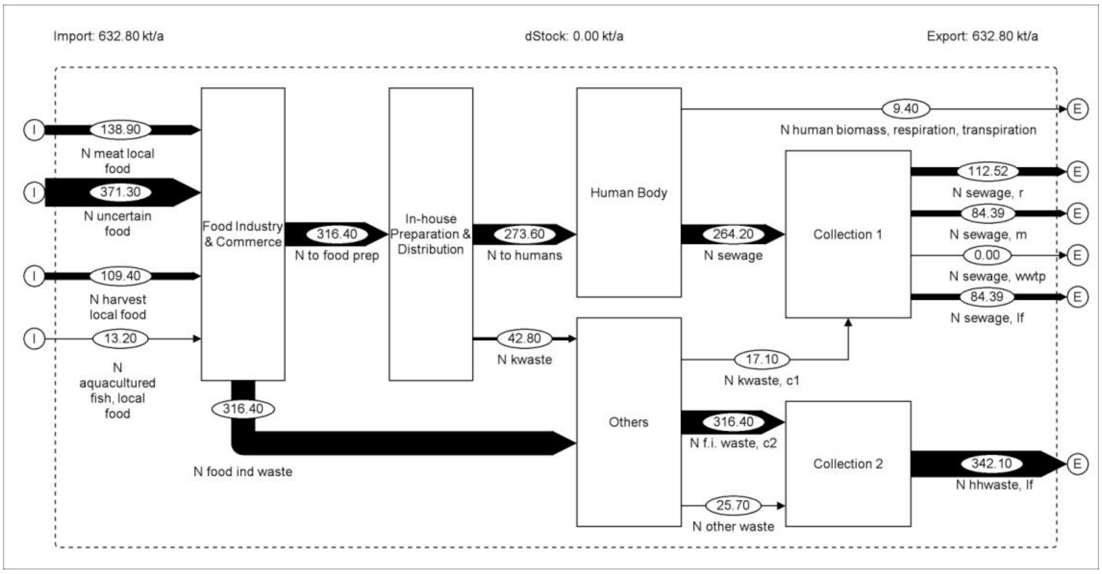
Nonetheless, the SFA computes for the difference between the input to the process *Fish Breeding* and *N to harvest*. This sum is both N fish excretions and residual nutrients from the feeds and algal fertilizers.

In this case, wastewater treatment plants are non-existent hence the output flow *N aqwaste, wwtp* will be considered 0. Nonetheless, the researcher included wastewater treatment, as it can be a viable intervention in the future. The next output flow is *N aqwaste, r* representing the wastes from aquaculture that reaches the river. This can take up majority of the wastes as long as aquaculture is done in ponds situated in the near river systems or on river systems themselves. According to the Bureau of Fisheries and Aquatic Resources of the Philippines there are 239,323 hectares of existing fishpond, 139,735 hectares of swampland, and 250 hectares of other inland resources (lakes, rivers, reservoirs) (Bureau of Fisheries and Aquatic Resources Phil, 2009). Hence in this model the researcher will assume that the *N aqwaste, r* has is 90% of *N fish excr* plus the N residues. This output flow directly goes to another process *Rivers* in the country sub-system.

Nonetheless, this study will account also for aquaculture now done directly in fish cages in the sea. It is alarming to know that this is a growing trend and has found some proponents even amongst biologists in the Philippines. This waste as a by-product of aquaculture in seas will be called the output flow *N aqwaste, marine*. These fish cages would most probably be commercial/industrial aquaculture. In the researcher's January 2012 visit to Anilao, Philippines new fish cages for carnivorous fish have been cropping up. These are small to medium scale installations that may not have been included in the computations for aquaculture areas. Hence waste to sea will be this percentage be assumed to be 10%.

A.1.c Philippines-To Nourish Sub-system for Nitrogen

Figure 11. N To Nourish Sub-system, Philippines (kt/a)



To compute for the N intake of the Philippines, an input (*N to humans*) is fed into the process *Human Body* . Basically this is the edible portion ingested by the human body:

***N to humans*=Po x IntN**

Where:

Po=population

IntN=per capita intake of N per year

N to humans= 85,500,000 x 3200 grams/annum

***N to humans*=273,600 tons/annum**

The data for Nitrogen per capita/annum of 3200 g was culled from the book Metabolism of the Anthroposphere (Baccini and Brunner, 1991).

The N from inedible and edible kitchen waste is represented by another flow, of which the values *Nks* and *Nkg* were also culled from Baccini and Brunner's Metabolism of the Anthroposphere.

***N kwaste*=Po (Nks + Nkg)**

Where:

Po=population

Nks=per capita N from kitchen waste that goes to sewage

Nkg=per capita N from kitchen waste that goes to garbage

N kwaste= 85,500,000 (200 grams/annum + 300 grams/annum)

N kwaste =(17,100 tons/annum + 25,650 tons/annum)

***Nkwaste*=42,750 rounded to 42,800 tons/annum**

***N kwaste, c1*=17,100 tons/annum**

***N to other waste*= 26,650 tons/a**

Nevertheless, this N intake is simply what humans consume. Food products from the farm, aquaculture, other food (imported food and sea catch) go through food companies who more often than not process the raw products thereby producing waste. According to Prof. Brunner, an estimated amount equal to food consumption goes to food processing and food commerce waste (Brunner, 2012). The SFA above computes for this. Hence *N to food prep* and *N ind waste* have the same values: the sum of *N to humans* and *N kwaste*.

The rest of the N that does not go to sewage is the sum of what is retained by the human body and then transpired and respired. According to Baccini and Brunner, 490 grams of N are excreted as solid wastes per capita and year while 2600 grams of N are excreted as urine. At the same time, 110 grams of N are lost through respiration and transpiration (Baccini and Brunner, 1991).

To compute for the outflow *N sewage* this is the formula:

***N Sewage*=Po (UrN + FcN)**

Where:

Po= estimated population

UrN=amount of N a human urinates per annum

FcN=amount of N a human excretes (solid wastes) per annum

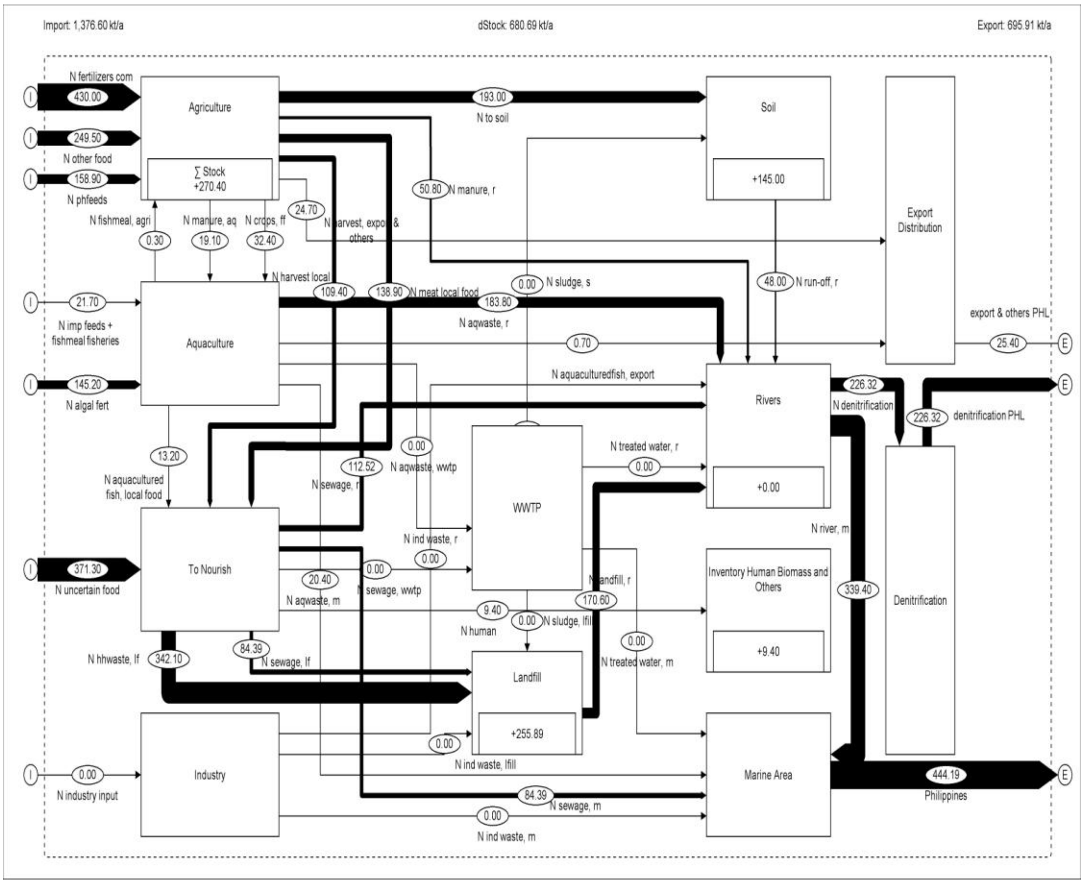
N Sewage=85,500,000 (2600 + 490)

***N Sewage*=264,195 rounded to 264,200 tons/annum**

N sewage then enters another process called *Collection 1*. The outflow of *Collection 1* are the following: *N sewage, r* (this goes to the process *River* in the country sub-system); *N sewage, m* (going to the process *Marine Area*), N sewage, lf (going to the process Landfills) and *N sewage, wwtp* (theoretically going to a sewage and wastewater treatment plant). In this model, the researcher is assuming transfer coefficients. It is a fact that the Philippines does not treat its sewage and water. Eventually, even the sludge of septic tanks are either placed in a landfill without treatment or dumped in rivers and even the ocean. The researcher is also taking into consideration the number of villages which do not have septic tanks and hence dispose of their sewage directly at sea. Hence the transfer coefficients assumed in this study will be 40% for *N sewage, r*; 30% for *N sewage, m*; 30% for *N sewage lf*, and 0% for *N sewage, wwtp*.

A.1.d Philippines-Country Sub-system for Nitrogen

Figure 12. N Country Sub-system, Philippines (kt/a)



(See Annex 1 for a full-page diagram)

There are numerous inflows to the process *Landfill*. However, since the process *Industry* is not taken into account in this study, its inflow into *Landfill* is pegged as zero. Same with *WWTP* which until recently was never used as an intervention in the Philippines. When the researcher started this study, Maynilad Water was still in the process of bidding to sub-contractors for their wwtps. As of August when the researcher checked Maynilad Water's website there have been notices to encourage households in a very few pilot districts of Metro Manila to avail of this service. Hence inflows and outflows to and from the process *WWTP* are all pegged at zero.

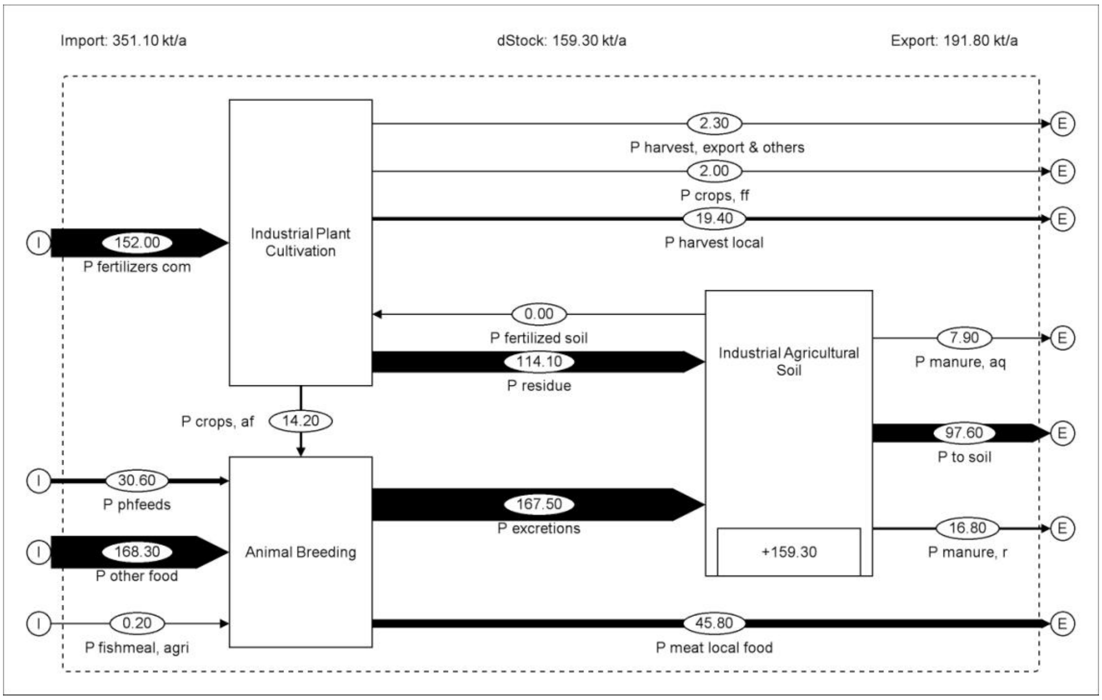
It is then assumed that of this N% content of household waste in landfills, 60% goes to stock while, 40% goes to leachate. These figures are based on a 2001 study of the Environmental Federal Office, Vienna or Umweltbundesamt GmbH Wien (Brunner et. al., 2001). Because the Philippines has no treatment of leachate in its landfills the researcher is assuming that all of these N in leachate are passed on to the rivers. This transfer coefficient of 40% is what one can see in the figure above represented by *N landfill, r*. This information on landfills was culled from an interview with the researcher's landfill professor, Johann Fellner (Fellner, 2012).

The process *Soil* has an input flow from agricultural soil. The researcher is estimating a run-off percentage of 25% of the total N that leaches to *Soil. N run-off, r* then leaches into *Rivers*. There are two output flows from Rivers. One is *N denitrification,* representing nitrogen in *Rivers* that goes through denitrification, a series of reactions that converts the N into product compounds. This will not be detailed in this study. The process *Denitrification* takes 40% of the N from *Rivers*, which is an estimate suggested by Professor Zessner (Zessner, 2012). An estimated 60% of the N from *Rivers* find their way into the *Marine Area* of the Philippines. This load of N is joined by other input flows from *To Nourish* and *Agriculture*. This total N load of 444,190 tons/annun to *Marine Area* is the Philippine's contribution to the N in the Coral Triangle.

A.2. Philippines-Phosphorus Sources, Pathways and Sinks

A.2.a. Philippines-Agriculture Phosphorus Sub-system

Figure 13. P Agriculture Sub-system, Philippines (kt/a)



This sub-system will again be patterned after the *Agriculture N Sub-system*, only the values for P will be used instead of N.

The first process in this sub-system is *Industrial Plant Cultivation*. The input flow that goes into this process is *P Fertilizers Com* representing the Phosphorus content of fertilizers applied in agricultural areas for a given year. For this data, the researcher subscribed to FAO's fertilizer database. The latest results were from 2001 and it denoted that the Philippines has 135,610 tons of P/a from commercial fertilizers applied to the cultivation of crops (FAOSTAT, 2012a). Furthermore an FAO graph shows that there was indeed an increase of fertilizer use in the Philippines (Reyes et. al., 2008). The researcher extrapolated from the graph and found an approximate increase of 12% from fertilizer usage in 2001 to 2005. Because the only complete data FAO has on P composition is for 2001, the researcher multiplied 135,610 tons N/a by 12% and adding it to the 2001 value achieving an estimated 2005 value of 151,883 rounded to 152,000 tons/a as an input of P from commercial fertilizers.

The ouptut flows from *Industrial Pant Cultivation* are five-fold. These output flows to be discussed are the amounts of P that find themselves in crop harvests. These flows are represented by the following: *P crops, af* (animal feeds); *P crops, ff* (fish feeds); *P residue* (N which is not used up by the plants and is passed on to *Agricultural Soil)*, *P harvest, local food* (crops consumed by local populace); *P harvest, export* (crops exported to other countries). All flows add up to Products from Plant Cultivation plus the difference between the input flows to *Industrial Plant Cultivation* and the Products from Plant Cultivation.

***Products from Plant Cultivation*=Crq x Pcr**

Where:

Crq=quantity of crop harvests per annum

Pcr=P percentage in crops

***Products from Plant Cultivation*=70,174,000 tons/a x 0.0006**

=42,104.4 rounded to 42,100 tons/a

The figure for the annual crop harvest was based on adding the crops outlined by FAO statistics for 2005 (Atovero and Borromeo, 2007). These crops include rice, maize, cassava, bananas, sugar cane, tropical fruits and vegetables and all plant produce. To achieve an average crude protein percentage the researcher culled the following data (Ciba Geigy, Lentner ed., 1981)

Rice=94mg/100 g edible portion=0.00094

Potato=53mg/100 g edible portion=0.00053

Corn grits=164mg/100 g edible portion=0.00164

Bananas=42mg/100 g edible portion=0.00042

Mango=13 mg /100 g edible portion=0.00013

Asparagus=62 mg/100 g edible portion=0.00062

Eggplant=26 mg/100 g edible portion=0.00026

Averaging the above, one gets a value of 0.06% P percentage. The researcher also assumed a value of 10% of the Products of Plant Cultivation such as rice stalks, and other plant material left on the fields and used as an organic fertilizer. This 10% along with the difference between inflows to Industrial Plant Cultivation and Products of Plant Cultivation make up the flow *P residue*.

To Local Industrial Crops= 42,100 x 0.028=1,178.8 rounded to 1,200 tons/annum

P harvest export=42,100 x 0.027=1,136.7 rounded to 1,100 tons/annum

Adding the above values for export and local industrial crops one gets the value for the outflow *P harvest export & others*.

There is also part of crops that are used as animal feeds and hence is an input to *Animal Breeding*. For this flow the researcher is using data culled from a report of the Canadian Agri-Food Trade Service (Canadian Agri-Food Trade Service, 2009a). The following formula is used:

P Crops, af **={(Afq x Cap) x (Pcp + Hcp) x Pfc}**

Where:

Afq=quantity of total animal feeds

Cap=percentage of total animal feeds from local crops

Pcp=percentage of local crops that goes into poultry feeds

Hcp=percentage of local crops that goes into hog feeds

Pfc= average percentage of P in feed crops=0.40% (Tacon, 1990)

P Crops, af **=(6,000,000 tons/a x 0.67) x (0.55 + 0.33) x 0.004}**

=14,150.40 rounded to 14,200 tons/a

The STAN program then automatically computes for *P harvest, local food* also an input flow to the *Households* sub-system

The researcher found data on poultry and hog feeds for the year 2009 (Canadian Agri-Food Trade Service, 2009a). To compute for this inflow of feeds, the researcher has this formula:

P, Phfeeds= **{(Icq x Ppi) x (Pip + Hip) x Pfc} + {(Icq x Pfp) x (Pip +Hip) x Pmp} +Pfa**

Where:

Icq=quantity of imported commercial feed ingredients

Ppi=percentage of plant material from these feed ingredients

Pfp=percentage of fish meal from these feed ingredients

Pip=percentage of imported ingredients that go to poultry feeds

Hip=percentage of imported ingredients that go to hog feeds

Pfc=P percentage in crops for animal feeds

Pmp=P percentage of fishmeal in imported commercial animal feeds

Pfa=P in local fishmeal from wild caught fish that go to agriculture

{(Icq x Ppi) x (Pip + Hip) x Pfc}={(2,000,000 tons/a x 0.13) x (0.55 +0.33) x 0.004}

=915.2 rounded to 900 tons/a

{(Icq x Pfp) x (Pip +Hip) x Pmp}={(2,000,000 tons/a x 0.67) x (0.55 +0.33) x 0.0227}

= 26,767.8 rounded to 26,800 tons/a

Pfa=2,860.5 rounded to 2,900 tons/a (See page 47 for computations)

***P, Phfeeds*= 900 tons/a + 26,800 tons/a+2,900 tons/a=30,600 tons/a**

The output flow from *Animal Breeding* is *P excretions*. Unlike N, there are no estimates available on the percentage of P in animal excretion.

Nonetheless excretion depends on the amount of feed of the animal. In a study done on "Nutrient Imports to Cape Fear and Neuse River Basins on Animal Feeds," it was mentioned that out of 100,000 metric tons of N in animal feeds used, P was 33,000 metric tons (Cahoon et. al., 1995). Of the 100,000 inputs of N in feed 33,000 tons were inputs of P. Therefore the researcher estimates that 33% of N excretions and 33% of N local food compose their P counterparts:

P, excretions=***N excretions* x 0.33**

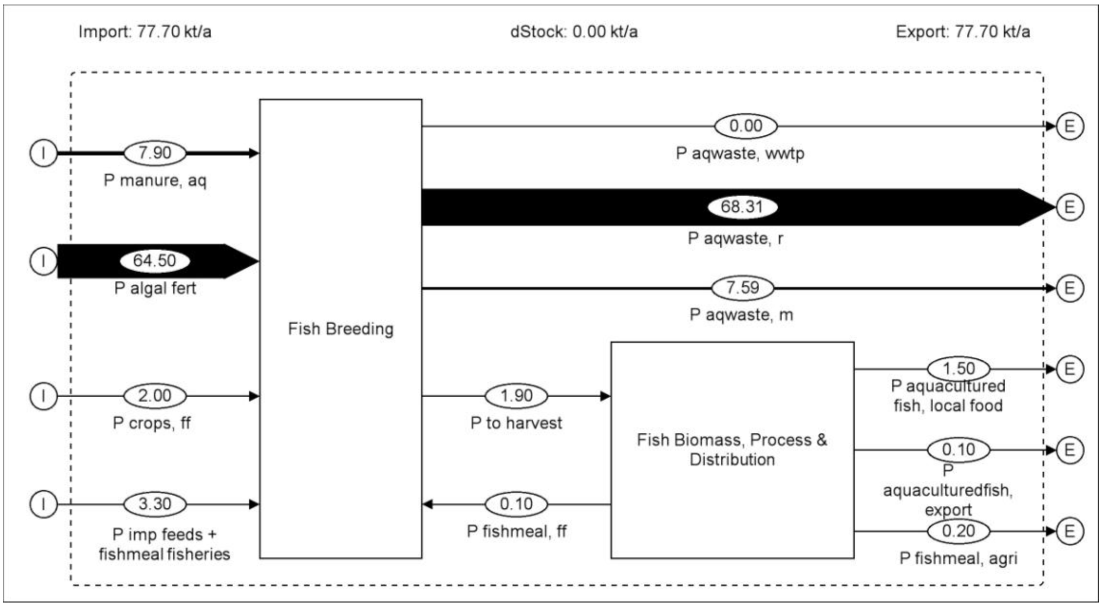
= 507,500 x 0.33= 167,475 rounded to 167,500 tons/a

***P meat local food*=*N meat local food* x 0.33**

=138,900 x 0.33=45,837 rounded to 45,800 tons/a

A.2.b Philippines Aquaculture Phosphorus Sub-system

Figure 14. P Aquaculture Sub-system, Philippines (kt/a)



To derive the Phosphorus inflows and outflows for the Philippines, the researcher is using the same SFA scheme and aquaculture statistics used in the N Aquaculture Sub-system of the Philippines. However, this time around the percentage values of P will be used instead of N. Furthermore, unlike in the N sub-systems where aquaculture feed ingredients and prepared feeds are given in their crude protein percentage, much of the studies detail the P content independent from crude protein. This is not surprising because protein consists mainly of Nitrogen, Carbon and Oxygen. There are even instances where in prepared feeds may be bereft of the substance P.

P_2O_5 occurs as 3.7% in poultry manure (Mitchel, et. al.). Phosphorus occurs as a percentage in this compound. Hence the researcher will further isolate the portion of the substance P:

P_2O_5

P= 2 x 30.974 grams/mole=61.948 g/mol

O=5 x 15.999 g/mol=79.995 g/mol

Molecular mass of P_2O_5= 141.943 g/mol

Proportion of P in P_2O_5=61.948g/mol/141.943 g/mol=.4364 or 43.6%

***P manure, aq*= M x MaP x Proportion of P in P_2O_5**

Where:

M=amount of chicken manure from domesticated animals used by the aquaculture industry in tons/year.

MaP= percentage of P_2O_5 in a particular animal manure used in the aquaculture industry. In this case it is 3.7% of the mass of chicken manure (Mitchel, et. al.).

***P Manure, aq*=489,998 tons x 0.037 x 0.436**

=7,904.6 rounded to 7,900 tons/a

The values for algal fertilizers below were culled from the study of 2007 study of Sumagaysay-Chavoso used in the previous chapter on N Aquaculture.

i. Monoammonium Phosphate $(NH_4)H_2PO_4$

N=1 x 14.007=14.007

H=6 x 1.0079=6.0474

P=1 x 30.974=30.974

O=4 x 15.999=63.996

Molecular mass of $(NH_4)_3PO_4$ =115.0244 g/mol

Proportion of P in Monoammonium Phosphate=30.974 g/mol/115.0244 g/mol

=0.2693 or 26.9%

P in Monoammonium Phosphate=0.269 x 158,666 tons/a

=42,681.154 rounded to 42,700 tons/a

ii. Diammonium Phosphate $(NH_4)_2HPO_4$

N=14.007 x 2=28.014

H=9 x 1.0079=9.0711

P=1 x 30.974=30.974

O=4 x 15.999=63.996

Molecular mass of $(NH_4)_2HPO_4$=132.0551 g/mol

Proportion of P in Diammonium Phosphate=30.974 g/mol /132.0551g/mol

=0.23455 or 23.5%

N in Diammonium Phosphate= 0.2350 x 18,087 tons/a

=4250.445 rounded to 4300 tons/a

iii. P_2O_5 in NPK- 0.14 x 286,946 tons/a=40,172.44 tons/a

Total P in NPK= 0.436 x 40,172.44 tons/a=17,515.18 rounded to 17,500 tons/a

To determine the total P in algal fertilizers consumed in 2004, the total P for each of the fertilizer types are simply added:

***P algal fert*= ∑ P in Fertilizers**

P algal fert=42,700 tons/a + 4,300 tons/a + 17,500 tons/a

= **64,500 tons/a**

According to FAO some phosphorus percentages of the following crops are: Soybean meal 0.56% and Corn grain 0.24% (Tacon, 1990) averaging a mean Phosphorus percentage of 0.40%. It is the same P content in fish feeds.

i. *P crops, ff*= (Dcf xFp) x Aqp x Pfc

Where:

Dcf=domestic crop for feeds

Fp=percentage of feeds from plants

Aqp=percentage of feeds that go to aquaculture

Pfc=P percentage in crops used for feeds

***P crops,ff*= (6,000,000 tons/a x 0.67) 0.12 x 0.0040**

=1929.6 rounded to 2000 tons/a

This is also the output flow from the process *Industrial Plant Cultivation* in the succeeding *Agriculture* sub-system.

In this sub-system *P imp feeds + fishmeal fisheries* will stand for imported fish feeds plus trash fish from wild caught fisheries that go into aquaculture feeds. Imported feeds means the total amount of imported prepared feeds and commercial feeds manufactured from imported crops and imported fishmeal.

***P imp feeds +fishmeal fisheries*= (Imf x Pfp x Ppf) + (Imf x Icp x Aqp x Pfc) + (Imf x Mfp x Aqp x Pmp) +Plf**

Where:

Imf=quantity of imported fish feeds

Pfx=percentage of prepared fish feeds

Ppf=P percentage from prepared feeds (prawn feeds x share of prawn farming in the aquaculture market)

The only percentage for Phosphorus is for shrimp pellet feed and not for other fish feed in the Philippines, although milkfish, catfish and tilapia in the Philippines is also fed with fish feeds. This P percentage (*Ppp*) is 1.02% (Tacon, 1990). Produce from shrimp farming consists of approximately 2.7% of aquaculture production (FAO Fisheries and Aquaculture Dept., 2012a). *Ppf* then becomes prawn feeds multiplied by the share of prawn farming in the total aquaculture market of the Philippines.

Imf x Pfx x Ppf=2,000,000 tons/a x 0.02 x (0.0102 x 0.027)

=11.016 rounded to 11 tons/a

Where:

Icp=percentage of imported crop material in Imf

Aqp=percentage going to aquaculture instead of other animal feeds

Pfc=P percentage in crops for animal feeds

Imf x Icp x Aqp x Pfc= 2,000,000 tons/a x 0.67 x 0.12 x 0.0040

=643.2 rounded to 600 tons/a

Where:

Mfp=percentage of imported fish meal material in Imf

Pmp= P percentage from imported fish meal material

Fishmeal according to FAO data has a Phosphorus percentage of 2.27% (Tacon, 1990).

Imf x Mfp x Aqp x Pmp= 2,000,000 tons/a x 0.13 x 0.12 x .0227

=708.24 rounded to 700 tons/a

Plf=P from local wild caught trash fish that go into fish feeds for aquaculture (See page 46 for the computation of this value)

Plf=2,018.4 rounded to 2,000 tons/a

***P imp feeds + fishmeal fisheries*= 11 tons/a +600 tons/a + 700 tons/a + 2000 tons/a=3311 rounded to 3300 tons/a**.

In a study done comparing rabbit fish and sea bream, it was said that these 2 fish had a P content of which varied according to the seasons. Sometimes it was $P<0.05$ and sometime it was $P<0.001$ (Ghaddar and Saoud, 2012). In another study at the Tokyo University of Sciences it was found in that rainbow trout fed with an experimental diet of 7.8 kg of P/ton of fish had a retention rate of 35.9% making that 0.0028 kg P in a kg of fish or 0.28%. A control diet of 18.5 kg of P/ton of fish had a retention rate of 18.5% making that 0.0032 kg P in a kg of fish or 0.32% (Satoh et. al., 2003). In another study by the University of Michigan measuring P retention of catfish in China, for a diet containing 16.57 kg P/ton of fish, 4.11 kg P/ton of fish was retained. This makes the retention 0.411% or 0.0041kg P per kg of fish (Hayse-Gregson, 2011). The researcher opted to use this 0.4% P of fish bodyweight as catfish is one of the aqua-cultured species in Southeast Asia, and fishmeal a more concentrated form of dried fish used for animal feeds has P content of 2.2% (Tacon, 1990). Of course the values used in this study are merely estimates, and it is recommended to do an extensive study by aquaculture scientists if the exact amounts of P retained by certain species of aqua-cultured fish are needed.

***P to harvest*=Sgq x Pff**

Where:

Sfq=quantity of seafood (fish and crustacea) from aquaculture

Pff=P percentage in fish/seafood

P to harvest=**481,000 x 0.004 =1,924 rounded to 1,900 tons/a**

P fishmeal, ff is the output flow from *P aqua harvests* but an input flow to the first process *Aquaculture Areas*. It is computed by the following formula:

***P fish meal ff*= {(Afq x Fmp x.05) x Ffp} x Pmp**

Where:

Afq=quantity of animal feeds

Fmp=percentage of total animal feeds from local fish meal

Ffp=percentage that goes to fish feeds

Pmp=percentage of P in fishmeal

For this equation the researcher is using the Phosphorus percentage in fish meal from FAO which is 2.27% (Tacon, 1990). As in the Nitrogen sub-system, the researcher is assuming that only 5% of fishmeal comes from aquaculture. Most local fishmeal comes from small fish accidentally caught by big nets in the ocean. They are processed and a more concentrated form of nutrients is achieved.

***P fish meal ff*=(6,000,000 tons/a x 0.13 x 0.05) x 0.12 x 0.0227**

=106.236 rounded to 100 tons/a

P fishmeal from local fisheries (wild caught) to fish feeds or **Plf=(6,000,000 tons/a x 0.13 x 0.95) x 0.12 x 0.0227=2,018.4 rounded to 2,000 tons/a**

P fishmeal, agri is the output flow that comes from *Fish Biomass, Process and Distribution.* It is computed as the total share of harvests from aquaculture in the country that end up in animal feeds in agriculture. These feeds are both poultry and hog feeds. To compute for this output flow the following is the formula:

***P fishmeal, Agri*={(Afq x Fmp x Paq x 0.05) x (Pfp + Hfp) x Pmp}**

Where:

Paq=Percentage of local catch of the Philippines that goes to fish meal

Pfp=percentage of local fishmeal that goes into poultry feeds

Hfp=percentage of local fishmeal that goes into hog feeds

In this model, the researcher is assuming that only 5% of the total fishmeal comes from aqua-cultured species. The research views that this is a very plausible percentage of aqua-cultured fishmeal that goes into the total fishmeal used in hog and poultry feed.

***P fishmeal,agri*={(6,000,000 tons/a x 0.138 x 0.18 x 0.05) x (0.55 +0.34) x 0.0227}**

=150.5 rounded to 200 tons/a

Fishmeal from wild caught fish that go to animal breeding or **Pfa={(6,000,000 tons/a x 0.138 x 0.18 x 0.95) x (0.55 +0.34) x 0.0227}=2,860.5 rounded to 2,900 tons/a**

P fish export= P to harvest x 0.05=tons/a

P fish export=**1,900 tons/a x 0.05= 95 rounded to 100 tons/a**

P fish, local food is then automatically computed by the STAN program.

To compute for this the researcher is culling data from a study by Lazzari and Baldorotto where 8.7kg of N per 1000kg of fish is excreted, making it 0.87% (Lazzari and Baldorotto, 2008).

P fish excr=Sfq x Epf

Where:

Sfq=quantity of seafood (fish and crustacea) from aquaculture

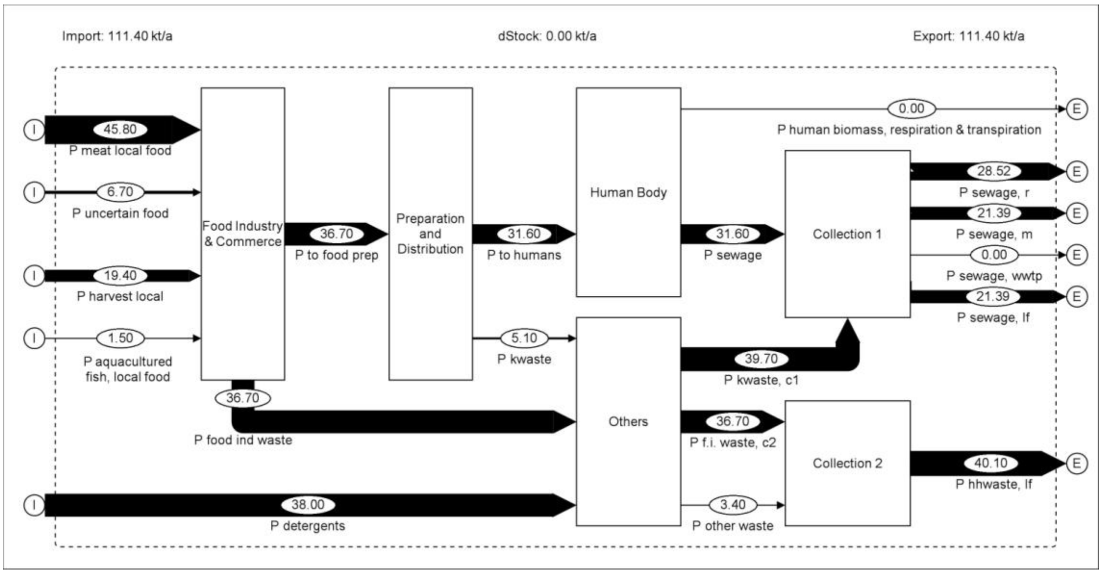
Epf=percentage of P excretion for every ton of fish=8.7kg per 1000 kg fish (Lazzari and Baldorotto, 2008)

P fish excr= 481,000 tons/a x 0.0087 =4,184.7 rounded to 4,200 tons/a

Fish excretion is not explicitly shown in the SFA as soluble and insoluble P in the water is lumped into three outflows: *P aqwaste, wwtp*; *P, aqwaste r*; *P, aqwaste m*; and *P, aqwaste, lf.* The SFA automatically solves for the value not retained by the fish as P.

A.2.c Philippines-To Nourish Sub-system for Phosphorus

Figure 15. P To Nourish Sub-system, Philippines (kt/a)



Like the previous *N To Nourish* sub-system, input flows to *Food Industry and Commerce* come from other sub-systems. It is only *P uncertain food* that is computed by the SFA based on the difference between the said input flows and *P to food prep*. *P to food prep* is the sum of *P to humans* and *P kwaste* computations discussed below and based on values from "Metabolism of the Anthroposphere" by Baccini and Brunner.

To compute for the P intake of the Philippines, an input (*P to humans*) is fed into the process *Human Body*. Basically this is the edible portion ingested by the human body:

***P to humans*=Po x IntP**

Where:

Po=population

IntP=per capita intake of P per year

P to humans= 85,500,000 x 370 grams/annum

***P to humans*=31,635 rounded to 31,600 tons/annum**

The data for Phosphorus per capita/annum of 370 g was culled from the book Metabolism of the Anthroposphere. Out of the 370 g per capita/annum, 270 grams of P go to urine and 100 g of P go to feces (Baccini and Brunner, 1991)

To compute for the outflow *P sewage* this is the formula:

***P Sewage*=Po (UrP + FcP)**

Where:

Po=population

UrP=amount of P a human urinates per annum

FcP=amount of P a human excretes (solid wastes) per annum

P Sewage=85,500,000 (270 + 100)

P Sewage= 23,085 + 8,550

P Sewage= **31,635 rounded to 31,600 tons/annum**

The body does not retain nor respire and transpire any Phosphorus (Baccini and Brunner, 1991). Hence the outflow from the *Human Body* to *human brt* (biomass, respiration, transpiration) is 0.

For every 60 grams/annum of P in kitchen waste, 20 grams go to sewage while 40 grams go to garbage (Baccini and Brunner, 1991).

***P kwaste*=Po (Pks + Pkg)**

Where:

Po=population

Pks=per capita P from kitchen waste that goes to sewage

Pkg=per capita P from kitchen waste that goes to garbage

P kwaste= 85,500,000 (20 grams/annum + 40 grams/annum)

P kwaste =(1,710 tons/annum + 3,420 tons/annum)

***Pkwaste*=5,130 rounded to 5,100 tons/annum**

***P other waste*=3,420 rounded to 3,400 tons/a**

Two thirty five thousand tons of detergents were used in the Philippines in 1996. Detergents in Southeast Asia contain 30% surfactants of phosphates (Satsuki, 1999). Therefore we will assume a per capita detergent consumption by dividing the consumption by the population of the Philippines in 1996. In 1996 the estimated population was 69,952,000 (Indexmundi, 2012a) rounded to 70,000.

Per capita consumption of detergent=235,000tons/70,000,000=3.4 kg per capita/annum of detergent.

Detergent consumption as of 2005= 85,500,00 x 3.4 kg=290,700 tons of detergent.

Percentage of phosphate= 290,700 x .30= 87,210 tons of detergent

Percentage of P=87,210 x 0.436=38,024 rounded to 38,000 tons of P/annum.

***P detergent*=38,000 tons/a**

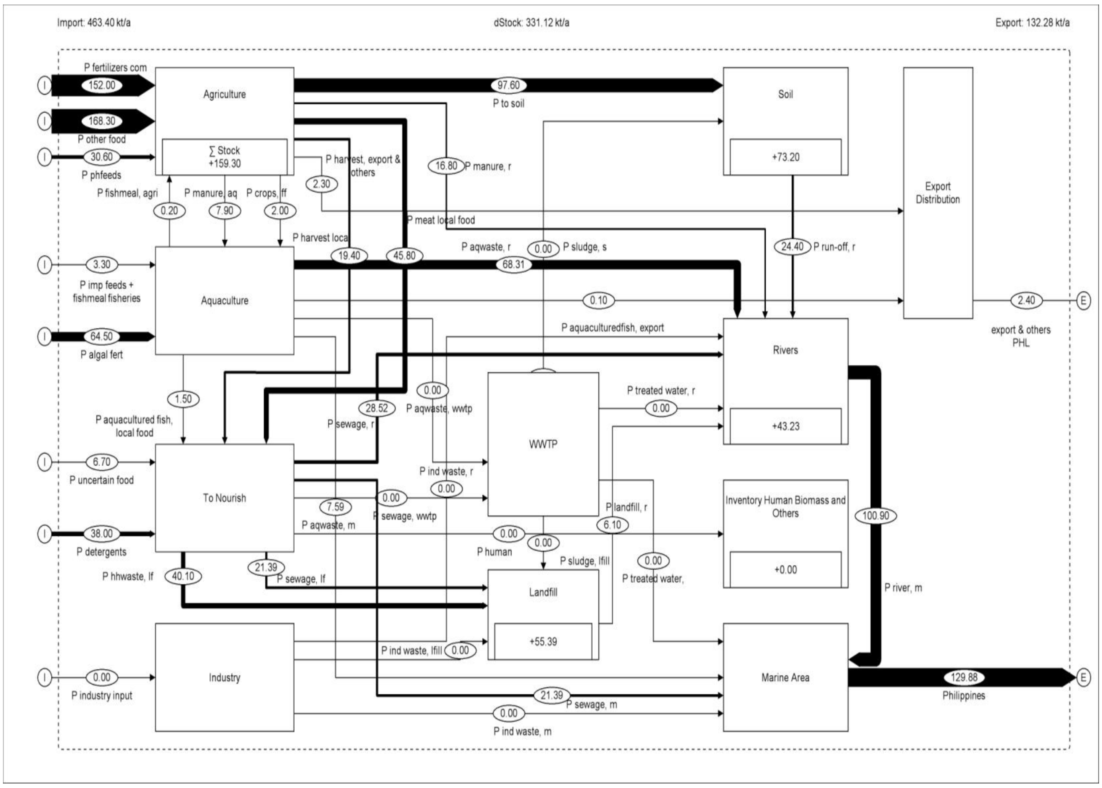
P kwaste, c1=(Pkwaste –P other waste) +P detergent

***P kwaste, c1*=(5,100 –3,400) + 38,000=39,700 tons/a**

P detergent joins the output flow *P kwaste, c1* to *Collection 1*. All al the rest of the transfer coefficients for Collection 1 follow that of the *To Nourish for N*.

A.2.d Philippines-Country Sub-system for Phosphorus

Figure 16. P Country Sub-system, Philippines (kt/a)



(See Annex 2 for a full-page diagram)

As with the N Country Overview, *Industry* is not taken into account in this study, its inflow into *Landfill* is pegged as zero. Same with *WWTP* which until recently was never used as an intervention in the Philippines and is only in the process of being introduced.

It is then assumed that of this P% content of household waste in landfills, 90% goes to stock while, 10% goes to leachate. These figures are based on a 2001 study by for the Environmental Federal Office, Vienna (Brunner et. al. 2001). Because the Philippines has no treatment of leachate in its landfills we are assuming that all of these P in leachate are passed on to the rivers untreated. This transfer coefficient of 10% is what one can see in the figure above represented by *P landfill, r*. The researcher gathered this information from an interview with Professor Fellner.

The process *Soil* has an input flow from agricultural soil. The researcher is estimating a run-off percentage of 25% of the total P that leaches to *Soil*. *P run-off, r* then leaches into *Rivers*. There is only one output flow from *Rivers*. An estimated 70% of the P from *Rivers* find their way into the *Marine Area* of the Philippines. This transfer coefficient must be verified by real measurements. A 90% transfer coefficient has a difference of 28.8 kilo tons or 28,800 tons from a transfer coefficient of 70%.

This load of P is joined by other input flows from *To Nourish* and *Agriculture*. This total P load of 129,880 tons/annum to *Marine Area* is the Philippine's contribution to the P in the Coral Triangle.

B. Malaysia

Malaysia is a middle income-economy with strong economic performance and the achievement of its "millenium development goals" of income, primary education, gender and wealth before its 2015 target (ADB, 2012b).

Malaysia for years has been one of Southeast Asia's vibrant economies, the fruits of political stability and industrial growth. It is one of the biggest manufacturers of disk drives and producers of industrial agricultural products such as palm oil, rubber and timber. It is predominantly a Muslim country with an economically powerful ethnic Chinese business elite.(BBC Country Profile, 2012).

Malaysia is also one of Southeast Asia's key destinations in terms of tourism. Beaches and dense rainforests in Sarawak and Sabah (East Malaysia) are a repository of wildlife and indigenous people's traditions (BBC Country Profile, 2012).

Figure 17-a. Map of Malaysia

Source: World Atlas (World Atlas, 2012)

The country is made up of two land areas separated by the South China Sea: Peninsular Malaysia (West Malaysia) and East Malaysia with the states of Sarawak and Sabah which are located in the island of Borneo (Hoegh-Guldberg et. al., 2009).

Figure 17-b. Map of East Malaysia

Source: Wikipedia “East Malaysia,” (Wikipedia, 2012b)

However, Sabah is the only Malaysian state included in the Coral Triangle (Hoegh-Guldberg et. al., 2009). Sabah’s shoreline on the northeast and southeast is adjacent to the Sulu and Celebes Seas falling within the Coral Triangle.

On the other hand, Sarawak’s shoreline faces the South China Sea excluded in the Coral Triangle Large Marine Ecosystem. Its eastern terrestrial border is adjacent Indonesia’s region of East Kalimantan that falls within the Coral Triangle.

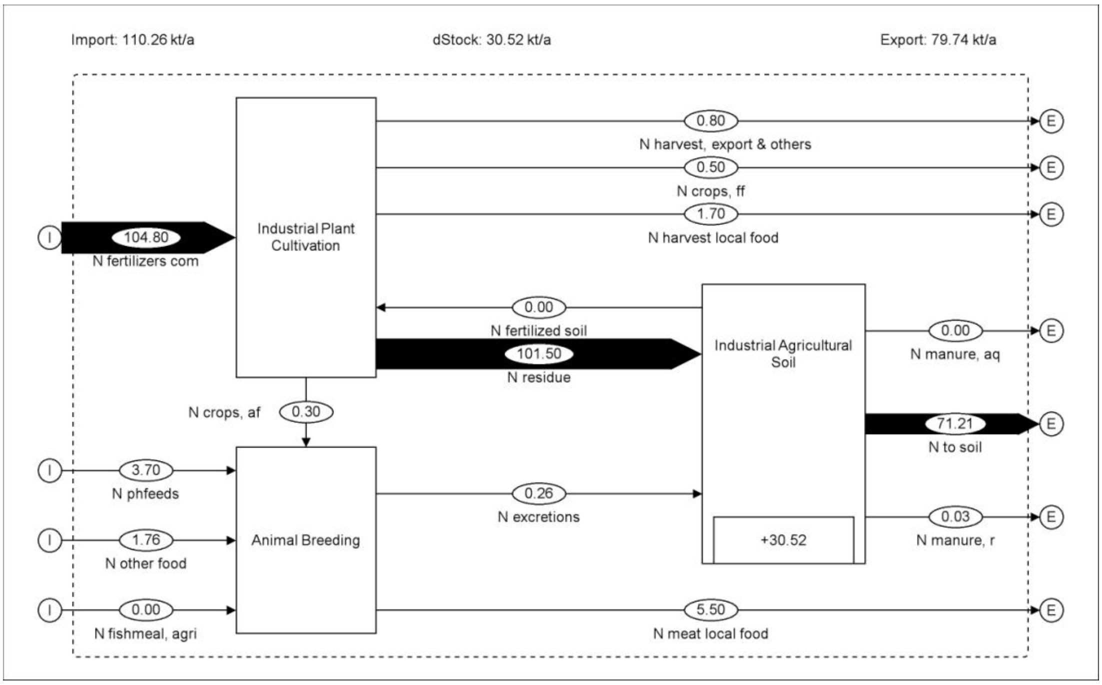
Sarawak border is made of mountains separating the state from Indonesia’s East Kalimantan (Wikipedia, 2012b). Hence in this study, the scenario only takes Sabah’s contribution to the CTLME.

Sabah covers an area of 76,111 sq km with a population of 3 million in 2005. Like other Malaysian states its urbanization rate has increased from 18% in 1970 to 49.5% in 2005 (Hoegh-Guldberg et. al., 2009).

B.1. Malaysia-Nitrogen Sources, Pathways and Sinks

B.1.a. Malaysia-Agriculture Nitrogen Sub-system

Figure 18. N Agriculture Sub-system, Malaysia (kt/a)



Malaysia is one of the world's largest producers of palm oil and natural rubber. Therefore it is not surprising that agriculture has been the third most important contributor next to the manufacturing and service sectors to Malaysia's economy. In 2003, the agriculture sector achieved a growth rate of 5.5% (FAO, 2004).

Sabah has a total arable land area of 2.15 million hectares while Sarawak has 5.31 million hectares (FAO, 2004). Therefore, in computations in this section wherein the numerical values found in studies for the two eastern states are lumped in one, the researcher will assume that 40% of the numerical value is Sabah's contribution.

In 2002, Malaysia consumed 351,000 tons of N and 364,000 tons of P_2O_5 in industrial, fruit, vegetables, cash crops and spices. Of these, industrial crops consumed 333,000 tons of N and 348,000 tons of P_2O_5 respectively. Oil palm is also considered to be the crop that consumes the highest quantity of fertilizers in Malaysia (FAO, 2004).

Based on FAO figures, the researcher added the tonnage of fertilizer used by crop and per region to achieve the total of N consumed in Sabah. Some of these industrial crops are rubber, oil palm, coconut, and cocoa, tobacco. The researcher also included rice, starchy crops, vegetables, fruits and spices. In crops, wherein there was no value for Sabah despite a yield and the number of hectares cultivated, the researcher used the known value of N per hectare multiplied by the given numbers of hectares cultivated as based on Sarawak's value.

N fert 2002 Sabah major crops=104,807 rounded to 104,800 tons/a

N fertilizers com Sabah **= 104,800 tons/a**

According to FAO, fertilizer use for oil palm and rubber have been declining due to conversion of rubber plantations to oil palm. Hence the researcher will take the 2002 estimates to be the 2005 estimates.

Although mineral fertilizers are estimated to be 90% on all crops in Malaysia, Potassium has by far the largest increase due to oil-palm agriculture. To reduce the dependency on mineral fertilizers, the Malaysian Government has been encouraging farmers to use recycled agricultural waste. This includes rice husks and straw, discarded empty oil palm bunches, animal droppings. In 2001, there were 27 organic producers in Malaysia covering 131 hectares, 12 hectares were in Sabah (FAO, 2004).

N Products from Plant Cultivation **=(Crq1 x Ppc1 x Npp)+(Crq2 x Ppc2 x Npp)+(Crq3 x Ppc3 xNpp)**

Where:

Crq=quantity of crop harvests per annum

Ppc1-Ppc3= average percentage of crude protein for each crop group.

Npp=nitrogen percentage in protein

Like the computations for Indonesia in the previous chapter, the researcher is grouping primary products together as PPC1 (*Products from Plant Cultivation 1*) and will use the 0.12 crude protein culled from averaging the crude protein of potatoes and rice (Ciba Geigy, Lentner ed., 1981). PPC2 *(Products from Plant Cultivation 2)* will be vegetables and fruits of which 0.032 crude protein will be used. Lastly PPC3 *(Products from Plant Cultivation 3)* will be industrial crops and beverages and tobacco of which a crude protein of .032 will also be used. The sum of the three is *N Products from Plant Cultivation.*

Starting with industrial crops, Sabah and Sarawak altogether produced 448 tons of rubber in 2002 while the whole of Malaysia produced 85,010 tons. Since there are no data on the individual contribution of Sabah and Sarawak, the researcher will use the percentage use in the computations of fertilizers where Sabah takes 40% of the share resulting to 179 tons of rubber for Sabah. For oil palm: Sabah has an estimated yield of 21,989 tons; East Malaysia 27,23. For cocoa: Sabah produced 30,422 tons; East Malaysia 32,859. For tobacco Sabah produced 1,723 tons while there is no data on Sarawak. For coconuts Sarawak had an estimated yield of 198.9 per hectares, there is no yield for Sabah so the researcher will assume the same for Sabah. Given 21,800 hectares of land in Sabah cultivated with coconuts, the yield per year would be 4,336 tons. East Malaysia yielded an estimate of 9,428 tons.

Industrial Crops *(PPC3)*:

Crop yield Sabah=179 +21,989 +30,422 +1,723 +4,300

=58,613 rounded to 58,600 tons

***PPC3 Sabah*=58,600 x 0.032 x 0.16=300 tons/a**

The following values were also culled from the FAO report on Malaysia (FAO, 2004):

Rice, Maize, Starches, and other cash crops *(PPC1)*:

Crop yield Sabah=137,200 +6,576 +424 +1756=145,956 rounded to 146,000 tons

***PPC1 Sabah*=146,600 x 0.12 x 0.16=2,814.72 rounded to 2,800 tons/a**

There are vegetable yields unavailable for Sabah. Only the area of cultivation was given. In those types of vegetables, the yield/hectare for Sarawak was followed.

Fruits:

Crop yield Sabah= 576 +15,066 +3,717 + 10,845 +1,449 +2098 +855 +9216 +2,385 +51,858 + 5,154 +3,304=106,523 rounded to 106,500 tons

Vegetables, Herbs and Spices:

Crop yield Sabah=920+514+500+1,651+1,836+1,024

=6,445 rounded to 6,400 tons/a

PPC2 Sabah=(106,500 + 6,400) x 0.032 x 0.16=578.04 rounded to 600 tons/a

***Products from Plant Cultivation Sabah*=300+2,800+600**

=3,700 tons/a

The researcher also assumed a value of 10% of the *Products of Plant Cultivation* such as rice stalks, and other plant material left on the fields and used as an organic fertilizer.

Furthermore, the researcher is assuming that 85% of industrial crops go to export while 15% of the other crops also go to export. Malaysia is said to export 85% of its oil palm crops (Encyclopedia of the Nations, 2012a). Sabah is also said to contribute 30% of the total exports of palm oil from Malaysia (Ismail, 2012)

***N harvest export Sabah*=(0.85 x 300) + {0.15 x (2,800+600)}**

=255 + 510=765 rounded to 800 tons/a

Malaysia's animal breeding industry largely consists of the poultry industry with 85% of total livestock production as of 2005. The pig and cattle industry consist of 9%

and 2% of livestock production. Every year, Malaysia consumes 3,000,000 tons of animal feed ingredients, 82% of which comes from maize, 12% from food processing waste, 1% from starchy roots, 3% from other cereals and 2% from milk. Hence the researcher will assume that 12% or 360,000 tons of these or food-processing waste is from domestic production. The researcher will also assume that this comes from crops. Furthermore, as of 2003 Malaysia imported 2.2 million tons of maize (Canadian Agri-Food Trade Service, 2009b). This leads the researcher to conclude that a huge chunk of maize used in animal feeds are imported while local production of corn is probably used for human consumption. Starchy residues and milk products like whey for animal feed are also imported (Canadian Agri-Food Trade Service, 2009b).

The researcher was not able to find data on the feed imports of Sabah nor East Malaysia. The researcher will then assume a consumption of feed based on 10% of local production of *PPC1* (rice, maize and starches) as the majority of food crops is used to feed the populace. The researcher is also assuming that the rest of animal feed is imported or taken from trash fish from sea catch.

***N Crops, af =*PPC1 x 0.10**

***N Crops, af Sabah =*2,800 x 0.10=280 rounded to 300 tons/a**

Animal Breeding have the following input flows: *N crops af*, *N phfeeds*, *N fishmeal, agri,* and *N other food. N, fishmeal agri* which is computed for in the *Aquaculture* sub-system.

To assume the value for *Plv* it is important to note that livestock production of Sabah is only 2% of the total production of Malaysia, while East Malaysia accounts for 8% of the total country production (Malaysian Govt., 2009).

N, Phfeeds=*(Afq x Plv x Cpp x Npp)-*N crops, af

Where:

Afq=Total animal feeds consumed in Malaysia

Plv=total percentage of livestock from Sabah

Cpp=crude protein percentage of animal feed used in other country computations; The crude protein percentage to be followed will be that of starchy crop materials and grains as soy bean does not figure in the animal feed structure of Malaysia.

Npp= N percentage of protein

***N, Phfeeds Sabah=*(3,000,000 tons/a x 0.02 x 0.42 x 0.16)-300**

=3,732 rounded to 3,700 tons/a

An output flow from *Animal Breeding* is *N, excretions*. There are several ways to compute for this. In this study the researcher, based on the data she found based her computations on this:

N, excretions=∑ animal heads per year x N excretion per animal per year

N, excretions=(Phq x Nep) + (Hhq x Neh) + (Rhq x Ner)

Where:

Phq=number of chicken heads per annum

Nep=N excretion in kg per chicken per year

Hhq=number of pig heads per annum

Neh=N excretion in kg per pig per year

Rhq=number of cows and buffalo per annum

Ner=N excretion in kg per ruminant per year

***N, excretions*= (Phq x Nep) + (Hhq xNeh) + (Rhq +Ner)**

***N, excretions Sabah*=(4,415 x 0.52kg) + (126 x 10.3 kg) + (414 x 53.6 kg)**

***N, excretions Sabah* =25.78 rounded to 26 tons/a**

The values for the number of heads for poultry, hogs, cattle and carabao (water buffalo) were based on a report of the Malaysian Agro-Food Statistics (Malaysian Govt., 2009). These are 2009 reports however and the researcher will use them as figures for 2005. The 2009 values from the real 2005 values may differ.

In Austria's Informative Report on Agriculture based on the year 2007, for chicken an excretion of 0.52 kg of N per animal per year is pegged (Anderl et. al., 2008). This is the same value the researcher is using for *Nep* in this paper. Fattening pigs are at 10.3 kg of N per animal while cattle 1-2 years is pegged at 53.6 kg of N per animal per year (Anderl et. al., 2008). The value for fattening pigs represent *Neh* in this study, while the value for cattle represent *Ner*.

For the N remaining in animal meat, the researcher is basing her figures on an interview with Professor Matthias Zessner of the TU Wien who has worked on nutrient loads in the Danube. In the interview Prof. Zessner approximated that, of 100% N intake, 30% goes to pork and chicken meat while 70% goes to excretion. For beef, 15% remain with the product, while 85% goes to excretion (Zessner, 2012). The researcher then derived the N that goes to the finish product such as meat, eggs, dairy products labeled *N meat local food.*

***N meat local food*=∑ N in poultry produce + N in pork produce + N in cattle and buffalo**

N in poultry produce={(Phq x Nep)/0.70} x 0.30

={(4,415 x 0.52kg) /0.70} x 0.30=983.9 rounded to 1000 tons/a

N in pork produce={(Hhq xNeh)/0.70} x 0.30

={(126 x 10.3 kg) /0.70} x 0.30=556.2 rounded to 600 tons/a

N in cattle and buffalo={(Rhq +Ner)/0.85} x 0.15

{(414 x 53.6 kg)/.85} x 0.15=3,915.9 rounded to 3,900 tons/a

***N meat local food Sabah*=5,500 tons/a**

There is a problem of leaching of fertilizers in Malaysia due to 2.4 million hectares of peat of which 0.1 million is located in Sabah (FAO, 2004). The researcher is assuming that oil palm plantations have been planted in former peat forests, much talked about by environmental NGO's. Hence, in the SFA above the transfer coefficient of N from *Industrial Agricultural Soil* to *Soil* after subtracting N manure, r is 70% while 30% remain as stock. In other *Agriculture* SFA's for the Philippines and Indonesia a transfer coefficient of 40% to *Soil* is used while 60% remains in *Industrial Agricultural Soil.*

B.1.b Malaysia- Aquaculture Nitrogen Sub-system

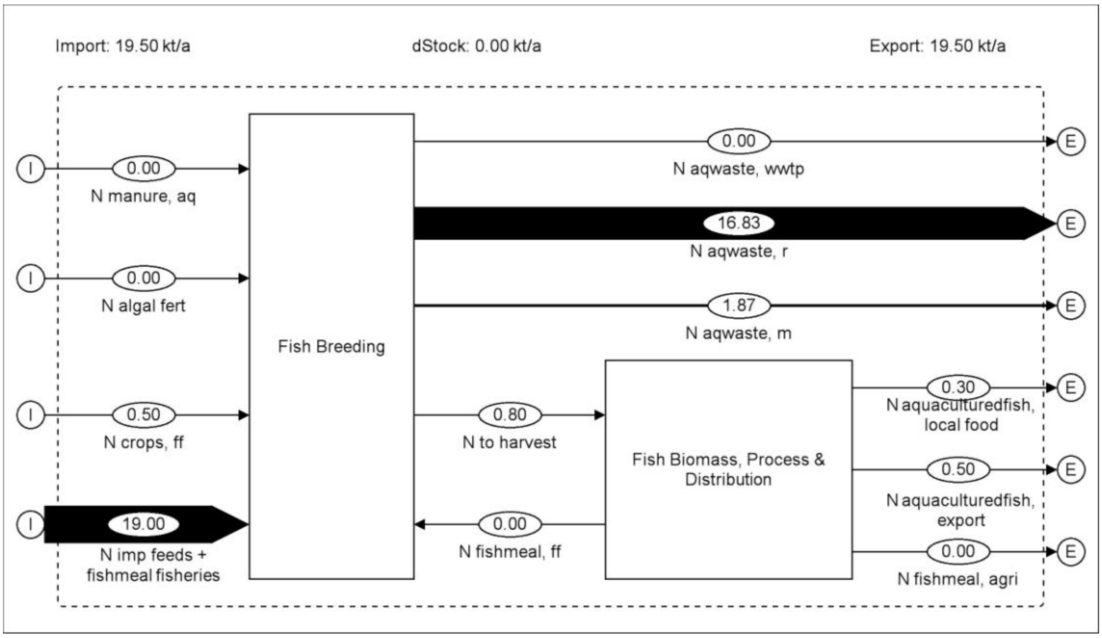
The Malaysian Government policy is actively encouraging investment in the aquaculture industry. There has been an increase in a number of marine and brackish water aquaculture. (Halwart et. al., 2007). Aquaculture in Malaysia is seen as increasing food security. Nevertheless, aquaculture is still small compared to the fisheries sector, with it contributing only 0.2 % to the country's GDP (FAO Fisheries and Aquaculture Dept., 2012c). In a study written by Hamdan et. al, it was mentioned that as of 2003, aquaculture contributed to 0.283 % of GDP, 0.3666 % in 2004 and 0.3% in 2006 (Hamdan et. al., 2012)

In the 1920's the aquaculture sector started to develop in Peninsular Malaysia where freshwater aquaculture was developed. Later in the 1930's brackish water aquaculture came into place. Nevertheless in Sabah and Sarawak aquaculture only began to take place in the 1990's (Hamdan et. al., 2012).

Given the long coastline of Malaysia, brackish water aquaculture contributed 144,189 tons in 2003, 70% of total aquaculture production. Bivalves contributed a significant amount to this production. Bivalve production occupies an area of 7,659 hectares. It is mostly done in the western coasts of Peninsular Malaysia. Land based dug out ponds have also spread and occupy 7,897 hectares. Most of these ponds are in Sabah where black tiger shrimp and marine fish are raised. Marine fish are also raised in floating cages in both lagoons and coastal waters occupying an area of 102 hectares. These areas are mostly in Peninsular Malaysia. The sea cages in Sabah are used mostly for seaweed production. Seaweed framing is done only in Sabah (FAO Fisheries and Aquaculture Dept., 2012 c). Nonetheless, cage-fish production has also been increasing in Eastern Malaysia particularly in Tuaran and Sandakan in Sabah. Of the 2000 estimates in cage farming, Sabah only took 9% of the share with most of the cage farming activities done in Peninsular Malaysia. There is no mention of Sarawak (Halwart et. al., 2007)

Sabah's economy is largely dependent on agriculture, forestry, and petroleum. But through the years aquaculture has slowly been playing a significant role. Although marine capture is the overall provider of fish, there is a significant amount of aquaculture both for local and export markets (Sabah Government, 2012). A study commissioned by UNEP detailed that out of 491,359 suitable hectares for aquaculture in Malaysia, Peninsular Malaysia occupies 159,633 hectares, Sabah 182,260 hectares and Sarawak 146,466 hectares (Bin Haji Omar et. al.).

Figure 19. N Aquaculture Sub-system, Malaysia (kt/a)



In an FAO study in 1984, it is detailed how some shrimp ponds use chicken manure as a food supplement for prawns in Peninsular Malaysia. The study further described how manure is not a useful food source for prawns, except that it provides N and P promoting a high production of bacteria comprising a small part of the food source of these prawns (Moriarty et. al., 1984)

In studies on Sabah there is no mention of the use of poultry manure as food supplements for aquaculture. In two studies done by Utama and Nuruddin and then by Sim and Williams both done in 2005, it is said that most of the aqua-cultured marine fish in Sabah does not make use of commercially prepared feeds. Instead trash fish is used as feeds. (Huey, 2007).

FAO describes that currently shrimp culture with stocking densities of at least 10 sq meters are dependent on commercial feeds, while for finfish or aqua-cultured marine fish trash fish is still the main source of nutrition (Utama, 1993). Hence, ***N manure, aq*** for Sabah and Eastern Malaysia will be pegged at 0 for this study. There is also no mention of the use of commercial algal fertilizers in Malaysian Aquaculture. Therefore ***N algal fert*** will also be pegged at 0 for this study.

Huey further describes that fishmeal from trash fish comes from two sources. The local fishmeal has a crude protein percentage of 70-74% while the imported ones have a crude protein percentage of 56-74%. Fish farmers use trash fish as a single source of feeds specially for carnivorous finfish culture. An estimated 85% of fish feeds for cultured marine fish come from trash fish. Trash fish consist of scad, mackerel, selar (Huey, 2007). They also include all marine fish from by-catch. For the purposes of this SFA the researcher will take 70% as the crude protein percentage of trash fish from local catch.

The researcher will then assume the consumption of feeds by showing both prawn and fish aquaculture. The feeds on prawns, a high-value export will be based on prepared pellet feeds, while for aqua-cultured fish 85% will come from trash fish and 15% from pellet feeds. In 2000, prawns produced were 5,200 tons (Sabah Government, 2012). Total marine/brackish water production was 7,000 tons including seaweed while total freshwater fish production is at 5,200 metric tons (Sabah Government, 2012). In 2001, a total of 10,520 tons of shrimp, finfish in cage aquaculture and finfish in freshwater ponds were produced aside from the 4,700 tons of seaweed grown in the sea (Sabah Government, 2012). The researcher will then assume based on the values for 2000 that 43% of the 2001 production of aquaculture is from prawns achieving an estimated value of 4,500 tons of prawns in 2001 and 6,000 tons of fish for the same year. To come up with figures for 2005, the researcher will used 10% annual growth rate for the past 10 years (FAO Fisheries and Aquaculture Dept, 2012c). Following this assumption for 2005, approximately 6,600 tons is the figure the researcher will be using in this study to approximate the value of prawns produced in Sabah. While 8,800 tons is the value estimated for aqua-cultured marine or carnivorous fish. There is no value of freshwater fish so following the 10% annual growth rate is computed from 2000 figures to approximately yield a harvest of 7,600 tons. These are non-carnivorous fish so the researching is making an educated guess that commercial feeds or farm-prepared feeds from both local and imported crops are used.

FAO further describes that the "AFCR" or apparent feed conversion rate in Malaysia is 2.5. Meaning to say that for every ton of fish and prawns produced 2.5 tons of pellet feeds prepared in Malaysia were used (Utama, 1993). Using this conversion an estimated 16,500 tons of commercial pellet feeds were used for the prawn industry in Sabah.

In a 2005 study done by Utama and Nurudin an estimated 9,235 tons of marine fish like sea bass, grouper and snapper were produced in Sabah in 2003. Consumption of trash fish was 94,000 tons (Huey, 2007). For this study the researcher will follow the 2003 values of 9,235 tons of aqua-cultured finfish fed with trash fish instead of her estimates of 8,800 tons for 2005. Following the "AFCR" concept of FAO, one needs approximately 10 tons of trash fish for 1 ton of fish.

Production of Aquacultured Marine Fish fed with Trash fish=9,235 rounded to 9,200 tons

Total Production of Aquacultured Marine Fish=9,200 tons/0.85

=10,823.5 rounded to 10,800 tons

Production of Aquacultured Marine Fish fed with other Feeds=10,800-9,200

=1,600 tons

Commercial Feed Consumption, Prawns & Fish={(6,600 tons +7,600 tons +1,600) x2.5}=38,000 tons of commercially prepared feeds

Trash Fish Consumption, Aquacultured Marine Fish=94,000 tons

In a 1983 report by FAO, it is described that Malaysia is highly dependent on imported feeds and ingredients for its aquaculture industry (Utama 1983). There is no certainty if that has changed through the years. However, the researcher is assuming that 70% of crop ingredients that go to commercial fish feed come from imported sources while 30% come from local sources. The researcher is also assuming that prepared feeds are largely crop based (70%) while some (30%) come from prepared imported pellets. The *Ccp* and *Npp* used in the computations below are the figures used for both the Philippines and Indonesia.

N crops, ff **={(Fpf x 0.70 x 0.30) x Cpp x Npp}**

Where:

Fpf=amount of ingredients that go to commercially prepared aqua-culture feeds.

Ccp=crude protein percentage from said crops

Npp=N percentage in protein

***N crops,ff Sabah*= (38,000 tons/a x 0.70 x 0.30) x 0.42 x 0.16**

=536.3 rounded to 500 tons/a

***N imp+fish feeds fisheries*= (Fpf x 0.70 x 0.70 x Cip x Npp) + (Fpf x 0.30 x Cfp x Npp) + (Tfi x Clf x Npp)**

Where:

Fpf=amount of ingredients that go to commercially prepared aqua-cultured feeds.

Tfi=imported trash fish ingredients that go to aquaculture feeds.

Clf=trash fish crude protein percentage; for the purposes of this SFA local trash fish from the marine catch/fisheries sector will be included in this value.

Cfp=crude protein percentage of prepared fish feeds; same values as used for the other 2 countries in the study.

Cip=crude protein percentage from imported crop materials; same as Cpp values

(Fpf x 0.70 x 0.70 x Cip x Npp)=38,000 tons x 0.70 x 0.70 x .42

=7,820.400 rounded to 7,800 tons/a

(Fpf x 0.30 x Cfp x Npp)=38,000 tons x 0.30 x 0.40 x 0.16

=729.6 rounded to 700 tons/a

(Tfi x Clf x Npp)=94,000 tons x 0.70 x 0.16

=10,528 rounded to 10,500 tons/a

***N imp+fish feeds fisheries Sabah*= 7,800 tons/a + 700 tons/a + 10,500 tons/a**

=19,000 tons/a

N in Aquaculture Harvests

***N to harvest*=Sgq x Npf**

Where:

Sfq=quantity of seafood (fish and crustacea) from aquaculture

Npf=N percentage in fish

***N to harvest Sabah*=(25,000 x 0.03)= 750 rounded to 800 tons/a**

N fishmeal,agri and N fish meal, ff as a product of aquaculture will be pegged as 0 for this study as the aquaculture studies of Malaysia shows that fish incorporated into aquaculture feeds come from the fisheries and imports and not the aquaculture sector.

Since the marine finfish fed with trash fish and prawns are high-value species, the researcher is assuming that these are exported out of Sabah. Sabah is one of the less affluent states of Malaysia. Aquaculture of high value species is seen as a way to increase the GDP of these areas. Furthermore, these products exported account for just over half of aquaculture production. The other half of aquaculture production as well as the fisheries sector is sufficient to sustain requirements of the local population.

According to FAO, most of the freshwater cultured fish in Malaysia is used for domestic consumption. The groupers and prawns are exported. Some countries that imports aqua-cultured produce from Malaysia are Japan, Taiwan, HK, Singapore, Australia, U.S. and the EU (FAO Fisheries and Aquaculture Dept., 2012 c).

***N fish export Sabah*= {(9,200 +6,600) x 0.03}**

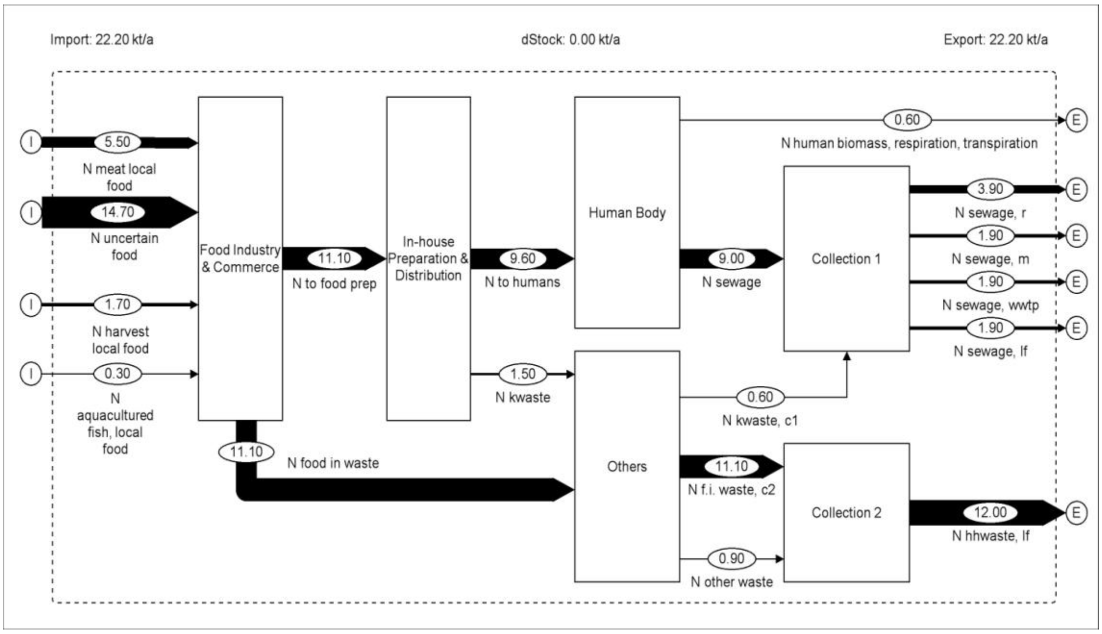
=474 rounded to 500 tons/a

***N fish export East Malaysia*= 500 x 1.8=900 tons/a**

N fish, local food is then automatically computed by the STAN program.

B.1.c Malaysia-To Nourish Sub-system for Nitrogen

Figure 20. N To Nourish Sub-system, Malaysia (kt/a)



To compute for the N intake of the Sabah, an input (*N to humans*) is fed into the process *Human Body* . Basically this is the edible portion ingested by the human body:

***N to humans*=Po x IntN**

Where:

Po=estimated population

IntN=per capita intake of N per year

N to humans Sabah=3,000,000 x 3,200 grams/annum

***N to humans Sabah*=9,600 tons/a**

The data for Nitrogen per capita/annum of 3200 g was culled from the book Metabolism of the Anthroposphere (Baccini and Brunner, 1991).

The N from inedible and edible kitchen waste is represented by another flow.

***N kwaste*=Po (Nks + Nkg)**

Where:

Po=population

Nks=per capita N from kitchen waste that goes to sewage

Nkg=per capita N from kitchen waste that goes to garbage

N kwaste Sabah= 3,000,000 (200 grams/annum + 300 grams/annum)

N kwaste Sabah =(600 tons/annum + 900 tons/annum)

***Nkwaste Sabah*=1,500 tons/annum**

***Nkwaste, c1*=600 tons/annum**

***N to other waste*=900 tons/annum**

Nevertheless, this N intake is simply what humans consume. Food products from farm, aquaculture, imported food and sea catch may go through processes in food companies and industries thus producing waste. According to Prof. Brunner, an estimated amount equal to consumption goes to waste (Brunner, 2012). The SFA above computes for this.

The rest of the N that does not go to sewage is the sum of what is retained by the human body and then transpired and respired. According to Baccini and Brunner, 490 grams of N are excreted as solid wastes per capita and year while 2600 grams of N are excreted as urine. At the same time, 110 grams of N are lost through respiration and transpiration (Baccini and Brunner, 1991).

To compute for the outflow *N sewage* this is the formula:

***N Sewage*=Po (UrN + FcN)**

Where:

Po= estimated population

UrN=amount of N a human urinates per annum

FcN=amount of N a human excretes (solid wastes) per annum

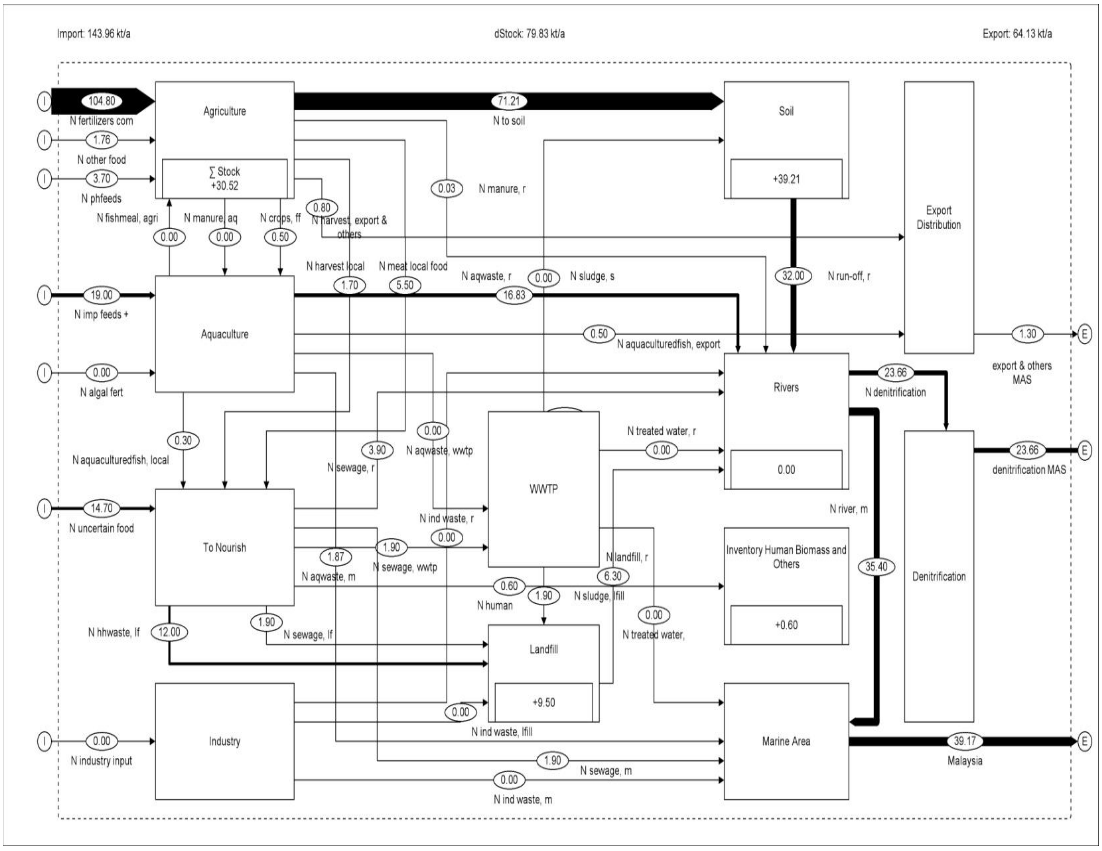
N Sewage Sabah=3,000,000 (2600 + 490)

***N Sewage Sabah*=9,270 rounded to 9,000 tons/annum**

N sewage then enters another process called *Collection 1*. The outflow of *Collection 1* are the following: *N sewage, r* (this goes to the process *Rivers* in the country sub-system); *N sewage, m* (going to the process *Marine Area*), N sewage, lf (this goes to the process Landfill in the country sub-system) and *N sewage, wwtp* (theoretically going to a sewage and wastewater treatment plant). Sabah is one of the poorest and underdeveloped states of Malaysia. Although in 2009 Malaysia had 8000 sewage treatment plans (APEC, 2009), the only data the researcher found on Sabah wwtps was a 2002 survey report on wastewater treatment plants in Sabah. Twelve percent (12%) of wwtp's are in operation. Of these only 8% was operating as planned. The wwtps serve 935,612 people or 30% of the population pegged in this study (Aripin, et.al., 2002). Eight percent (8%) of 30% is 24% rounded to 20%. In this model, the researcher is assuming transfer coefficients. Hence the transfer coefficients assumed in this study will be: 40% for *N sewage, r*; 20% for *N sewage, m*; 20% for *N sewage lf*, and 20% for *N sewage, wwtp*.

B.1.d Malaysia-Country Sub-system for Nitrogen

Figure 21. N Country Sub-system, Malaysia (kt/a)



(See Annex 3 for a full-page diagram)

Landfill has numerous flows from different sub-systems. Of which 1.9 kt of N come from WWTP; 1.9 kt of N is attributed to sewage dumped and 12 kt from household and food industry and commerce waste.

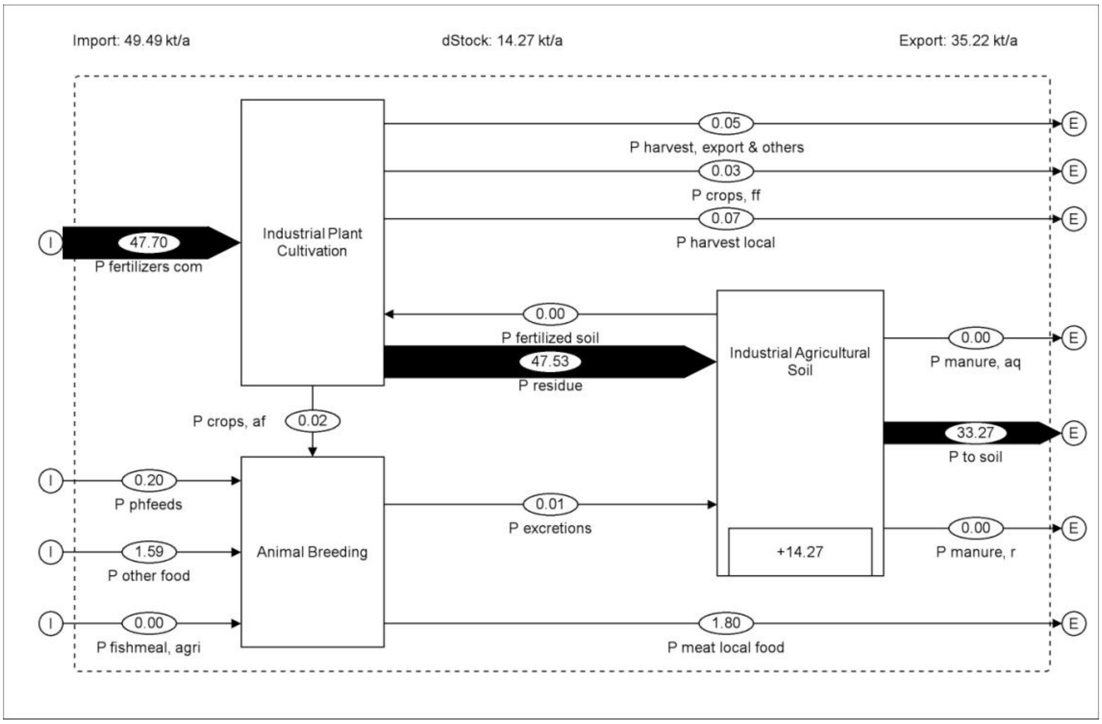
It is then assumed that of this N% content of household waste in landfills, 60% goes to stock while, 40% goes to leachate. These figures are based on a 2001 study by Brunner et. al. for the Environmental Federal Office, Vienna (Brunner et. al,). As with the Philippines and Indonesia, the researcher is assuming landfill leachate in Sabah is untreated and thereby finds its way to *Rivers*.

The process *Soil*, has a run-off of 45% of the total N while 55% remain as stock. As discussed earlier in this chapter, Sabah has a problem with leaching due to its peat soils. Rivers have two output flows: 40% are denitrified while 60% is passed on to *Marine Area*. These estimates were culled from interviews with Prof. Zessner (Zessner, 2012). Finally, 30.67 kt or 30,670 tons of N/annum is the contribution of Malaysia to the N load of the CTLME

B.2. Malaysia-Phosphorus Pathways and Sinks

B.2.a. Malaysia-Agriculture Phosphorus Sub-system

Figure 22. P Agriculture Sub-system, Malaysia (kt/a)



Based on FAO figures (FAO, 2004), the researcher added the tonnage of fertilizer used by crop and per region to achieve the total of P_2O_5 consumed in Sabah . Some of these industrial crops are rubber, oil palm, coconut, and cocoa, tobacco. The researcher also included rice, starchy crops, vegetables, fruits and spices. In crops, wherein there was no value for Sabah despite a yield and the number of hectares cultivated, the researcher used the known value of P_2O_5 per hectare based on Sarawak's value multiplied by the given numbers of hectares cultivated in Sabah.

P_2O_5 fert 2002 Sabah major crops=109,477 rounded to 109,500 tons

Using the percentage of P in phosphate in the previous computation, the researcher achieved the following values

***P fertilizers com Sabah*= 109,500 x 0.436=47,742 rounded to 47,700 tons/a**

***P Products from Plant Cultivation*=Crq x Pcr**

Where:

Crq=quantity of crop harvests per annum

Pcr= average percentage of P in crops

Like the computations for Indonesia in the previous chapter, the researcher is multiplying the total crop production by the estimated P concentration in a basket of crops.

Industrial Crops:

Crop yield Sabah=179 +21,989 +30,422 +1,723 +4,300

=58,613 rounded to 58,600 tons

The following values were also culled from the FAO report on Malaysia (FAO, 2004):

Rice, Maize, Starches, and other cash crops *(PPC1)*:

Crop yield Sabah=137,200 +6,576 +424 +1756=145,956 rounded to 146,000 tons

There are vegetable yields unavailable for Sabah. Only the area of cultivation was given. In those types of vegetables, the yield/hectare for Sarawak was followed.

Fruits:

Crop yield Sabah= 576 +15,066 +3,717 + 10,845 +1,449 +2098 +855 +9216 +2,385 +51,858 + 5,154 +3,304=106,523 rounded to 106,500 tons

Vegetables, Herbs and Spices:

Crop yield Sabah=920+514+500+1,651+1,836+1,024

=6,445 rounded to 6,400 tons/a

***P Products from Plant Cultivation Sabah*={(58,600+146,600+106,500+6,400) x 0.0006}=190.86 rounded to 190 tons/a**

The researcher also assumed a value of 10% of the *Products of Plant Cultivation* such as rice stalks, and other plant material left on the fields and used as an organic fertilizer.

Furthermore, the researcher is assuming that 85% of industrial crops go to export while 15% of the other crops also go to export. Malaysia is said to export 85% of its oil palm crops (Encyclopedia of the Nations, 2012a). Sabah is also said to contribute 30% of the total exports of palm oil from Malaysia (Ismail, 2012)

***P harvest export Sabah*=(0.85 x 58,600 x 0.0006) + {0.15 x (146,600+106,500+6,400) x 0.0006}=53.24 rounded to 53 tons/a**

Malaysia's animal breeding industry largely consists of the poultry industry with 85% of total livestock production as of 2005. The pig and cattle industry consist of 9% and 2% of livestock production. Every year, Malaysia consumes 3,000,000 tons of animal feed ingredients, 82% of which comes from maize, 12% from food processing waste, 1% from starchy roots, 3% from other cereals and 2% from milk. Hence the researcher will assume that 12% or 360,000 tons of these or food-processing waste is from domestic production. The researcher will also assume that this comes from crops. Furthermore, as of 2003 Malaysia imported 2.2 million tons of maize (Canadian Agri-Food Trade Service, 2009b). This leads the researcher to conclude that a huge chunk of maize used in animal feeds are imported while local production of corn is probably used for human consumption. Starchy residues and milk products like whey for animal feed are also imported (Canadian Agri-Food Trade Service, 2009b).

The researcher was not able to find data on the feed imports of Sabah nor East Malaysia so the researcher will assume a consumption of feed based on 10% of local production of rice, maize and starches multiplied by the a P percentage based on the average P in rice and corn grits from Ciba Geigy which is estimated at 0.00147 (Giba Geigy, Lentner ed., 1981)

***P Crops, af* =Total crop production of rice, maize etc x 0.10 x 0.001**

***P Crops, af Sabah* =146,600 x 0.10 x 0.001=14.7 rounded to 15 tons/a**

Livestock production of Sabah is only 2% of the total production of Malaysia, while East Malaysia accounts for 8% of the total country production (Malaysian Govt., 2009).

P, Phfeeds*=(Afq x Plv x Paf)-*P crops, af

Where:

Afq=Total animal feeds consumed in Malaysia

Plv=total percentage of livestock from Sabah/East Malaysia

Paf= P percentage in imported crops for animal feed based on previous country computations

***P, Phfeeds Sabah=*(3,000,000 tons/a x 0.02 x 0.004)-15**

=225 rounded to 200 tons/a

***N, Phfeeds East Malaysia*=(3,000,000 tons/a x 0.08 x 0.004)-30**

=930 rounded to 900 tons/a

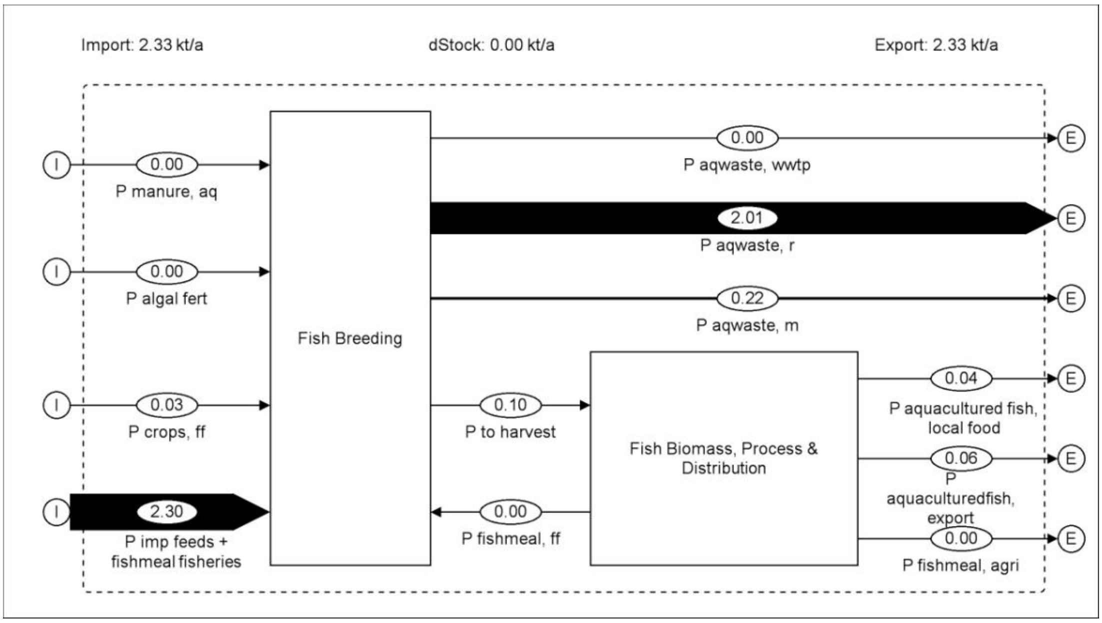
An output flow from *Animal Breeding* is *P,excretions*. Like in previous country computations, the researcher will be basing her data on a ration of N:P in the inputs of feed, as P retained is determined by the diet of the animal. The ratio used in the previous chapters were 1:0.33. As the amount of N in previous computations also depended o the input and excretion of substances, the values for P local meat will also be N local meat multiplied by 0.33.

***P, excretions Sabah* =26 tons/a x 0.33=8.6 rounded to 9 tons/a**

***P meat local food Sabah*=5,500 tons/a x 0.33=1,815 rounded to 1,800 tons/a**

B.2.b Malaysia- Aquaculture Phosphorus Sub-system

Figure 23. P Aquaculture Sub-system, Malaysia (kt/a)



This section will also follow the SFA on N except that P values are different. Like the N Aquaculture SFA, ***P manure, aq*** and ***P algal fert*** are pegged at 0.

Local Crops as Ingredients for Fishfeeds

***P crops, ff*=Fpf x 0.70 x 0.30 x Pfc**

Where:

Fpf=amount of ingredients that go to commercially prepared aqua-culture feeds

Pfc=P percentage in crops; same value used in previous country computations

***P crops,ff Sabah*= 38,000 tons/a x 0.70 x 0.30 x 0.004**

=31.92 rounded to 32 tons/a

***P imp + trash fish feeds*= (Fpf x 0.70 x 0.70 x Pfc) + (Fpf x 0.30 x Ppp) + (Tfi x Pmp)**

Where:

Fpf=amount of ingredients that go to commercially prepared aqua-culture feeds

Pfc=P percentage for feeds from crops

Ppp=P percentage prepared pellet feeds (Researcher is assuming that imported pellet feeds are used only for prawn culture, as commercial fin fish is fed fishmeal and commercial feeds from crop material).

Tfi=amount of both imported and local trash fish used in Sabah's aqua-culture industry

Pmp= crude protein percentage from trash fish; researcher is assuming the same value as P in fishmeal.

(Fpf x 0.70 x 0.70 x Pfc)= 38,000 tons/a x 0.70 x 0.70 x 0.004

=74.48 rounded to 75 tons/a

(Fpf x 0.30 x Ppp)=38,000 tons/a x 0.30 x 0.0102

=116.28 rounded to 100 tons/a

(Tfi x Pmp)=94,000 tons/a x 0.0227

=2,133.8 rounded to 2,100 tons/a

***P Imp feeds+tff, Sabah*= 75 tons/a + 100 tons/a + 2,100 tons/a**

=2,275 rounded to 2,300 tons/a

P in Aquaculture Harvests

In the computations for

***P to harvest*=Sgq x Pff**

Where:

Sfq=quantity of seafood (fish and crustacea) from aquaculture

Pff=P percentage in fish; same value as other country computations

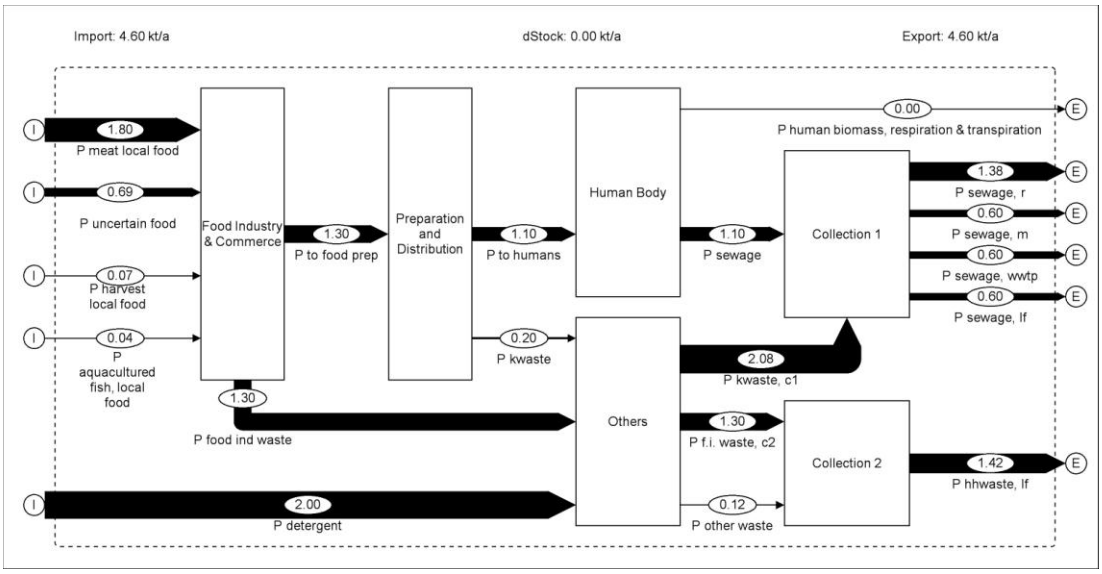
***P to harvest Sabah*=25,000 x 0.004=100 tons/a**

P fish meal ff and ***P fishmeal,agri*** are pegged as 0 just like in the N SFA.

***P fish export Sabah*= 15,800 tons/a x 0.004 =63.2 rounded to 60 tons/a**

B.2.c Malaysia-To Nourish Sub-system for Phosphorus

Figure 24. P To Nourish Sub-system, Malaysia (kt/a)



To compute for the P intake of the Indonesia, an input (*P to humans*) is fed into the process *Human Body*. Basically this is the edible portion ingested by the human body:

***P to humans*=Po x IntP**

Where:

Po=population

IntP=per capita intake of P per year

P to humans Sabah= 3,000,000 x 370 grams/annum

=1,110 rounded to 1,100 tons/annum

The data for Phosphorus per capita/annum of 370 g was culled from the book Metabolism of the Anthroposphere. Out of the 370 g per capita/annum, 270 grams of P go to urine and 100 g of P go to feces (Baccini and Brunner, 1991).

To compute for the outflow *P sewage* this is the formula:

***P Sewage*=Po (UrP + FcP)**

Where:

Po=population

UrN=amount of N a human urinates per annum

FcN=amount of N a human excretes (solid wastes) per annum

P Sewage Sabah=3,000,000 (270 + 100)

P Sewage Sabah= 810 + 300

P Sewage Sabah= **1,110 rounded to 1,100 tons/annum**

P sewage then enters another process called *Collection 1*. The outflow of *Collection 1* are the following: *P sewage, r* (this goes to the process *River* in the country sub-system); *P sewage, marine* (going to the process *Marine Area*) and *P sewage, wwtp* (theoretically going to a sewage and wastewater treatment plant). In this model, the researcher is assuming transfer coefficients. It is a fact that the does not treat its sewage and water. Eventually, even the sludge of septic tanks are either placed in a landfill without treatment or dumped in rivers and waterways. The researcher is also taking into consideration the number of villages which do not have spetic tanks and hence dispose of their sewage directly at sea. Hence the transfer coefficients assumed in this study will be 40% for *P sewage, r*; 20% for *P sewage, m*; 20% for *P sewage, lf* and 20% for *P sewage, wwtp*.

The body does not retain nor respire and transpire any Phosphorus (Baccini and Brunner, 1991). Hence the outflow from the *Human Body* to *human brt* (biomass, respiration, transpiration) is 0.

The P from inedible and edible kitchen waste is represented by another flow.

***P kwaste*=Po (Pks + Pkg)**

Where:

Po=population

Pks=per capita P from kitchen waste that goes to sewage

Pkg=per capita P from kitchen waste that goes to garbage

P kwaste Sabah= 3,000,000 (20 grams/annum + 40 grams/annum)

P kwaste Sabah=(60 tons/annum + 120 tons/annum)

***Pkwaste Sabah*=180 rounded to 200 tons/annum**

***P other waste Sabah*=120 tons/annum**

110,000 tons of detergents were used in Malaysia in 1996. Detergents in Southeast Asia contain 30% surfactants of phosphates (Satsuki, 1999). Therefore we will assume a per capita detergent consumption by dividing the consumption by the population of Indonesia in 1996. In 1996 the estimated population was 21,169,000 rounded to 21,000,000 while its 2005 population was 26,477,000 rounded to 26,500,000 (Indexmundi, 2012b). Hence the researcher is assuming Sabah has 11% of Malaysia's population in 2005.

Per capita consumption of detergent=110,000tons/21,000,000=5.2 kg per capita/annum of detergent.

Detergent consumption as of 2005= 26,500,000 x 5.2 kg=137,800 tons of detergent.

Percentage of phosphate= 137,800 x .30= 41,340 tons of phosphate

Percentage of P=41,340 x 0.436=18,024.4 rounded to 18,000 tons of P/annum

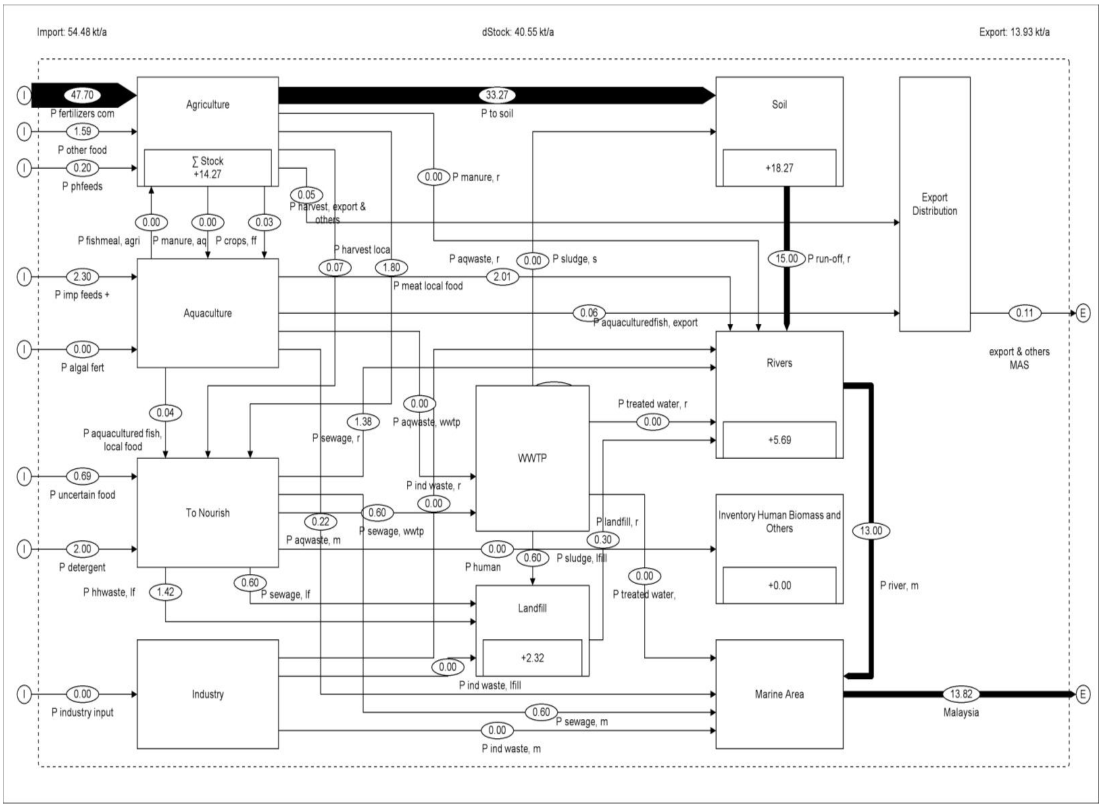
Percentage of P Sabah= 18,000 x 0.11=1,980 rounded to 2,000 tons/annum

***P detergent Sabah*=2,000 tons/annum**

***P kwaste, c1=(Pkwaste-P other waste)+ P detergent*= (200-120) +2000=2,080 tons/annum**

C.2.c Malaysia-Country Sub-system for Phosphorus

Figure 25. P Country Sub-system, Malaysia (kt/a)



(See Annex 4 for a full-page diagram)

Landfill has numerous flows from different sub-systems. Of which 600 tons of P come from WWTP; another 600 tons of N is attributed to sewage dumped and 1,420 tons of N from household and food industry and commerce waste.

It is then assumed that of this P% content of household waste in landfills, 90% goes to stock while, 10% goes to leachate. These figures are based on a 2001 study by for the Environmental Federal Office, Vienna (Brunner et. al. 2001). As with the Philippines and Indonesia, the researcher is assuming landfill leachate in Sabah is untreated and thereby finds its way to *Rivers*.

The process *Soil*, has a run-off of 45% of the total N while 55% remain as stock. As discussed earlier in this chapter, Sabah has a problem with leaching due to its peat soils. These estimates were culled from interviews with Prof. Zessner (Zessner, 2012).

Rivers pass on 70% of N to *Marine Area*. It is important to note that a transfer coefficient of 90% may be possible and hence will yield close to 4,000 tons of N more than what is in the SFA. Finally, 13 kt or about 94% of the total N load of Sabah to the CTLME come from *Rivers*. The total N load of Malaysia to the CTLME is 13.82 kt or 13,820 tons of N/annum

C. Indonesia

Indonesia is the largest archipelago in the world. It is rich with plant and animal biodiversity both terrestrial and aquatic. Most of Indonesia with the exception of Bali is Muslim. Religion plays a great role in society in these islands. Indonesia's economy has strongly expanded after the 1997 Asian Financial Crisis. Despite the recent global crisis, Indonesia's economy increased at 4.9% making it one of the best performers during the global recession. In 2010 GDP growth was 6.1 % mostly because of domestic consumption and increased investment and export (ADB, 2012c).

Indonesia with its 17,500 islands has its eastern part falling within the Coral Triangle. These 15 provinces within the Coral Triangle consist of 1,000,0000 square kilometers. The following provinces within East Indonesia shown in the map below are: Bali; West and East Nusa Tenggara; North, South, Southeast, Central and West Sulawesi; Papua and West Papua; East and South Kalimantan; Maluku and Maluku North; and Gorontalo (Hoegh-Guldberg et.al, 2009).

Figure 26. Map of Indonesia

Source: Wikipedia "Indonesia," (Wikipedia, 2012c)

Nevertheless the population of East Indonesia accounts only for 17% of the country's population. Population growth is declining in other parts of Indonesia other than in Eastern Indonesian (Hoegh-Guldberg et.al, 2009).

According to Indonesia's National Census, in 2010 the country had an estimated population of 237,641,326 (Badan Pusat Statistik, 2012a). The Asian Development Bank pegs Indonesia's 2010 population as 234,180,000 (ADB, 2012c). In 2005, Indonesia has an estimated population of 219,852,000 (Indexmundi, 2012c). In this study, the researcher will use the value 220,000,000 to represent the population for

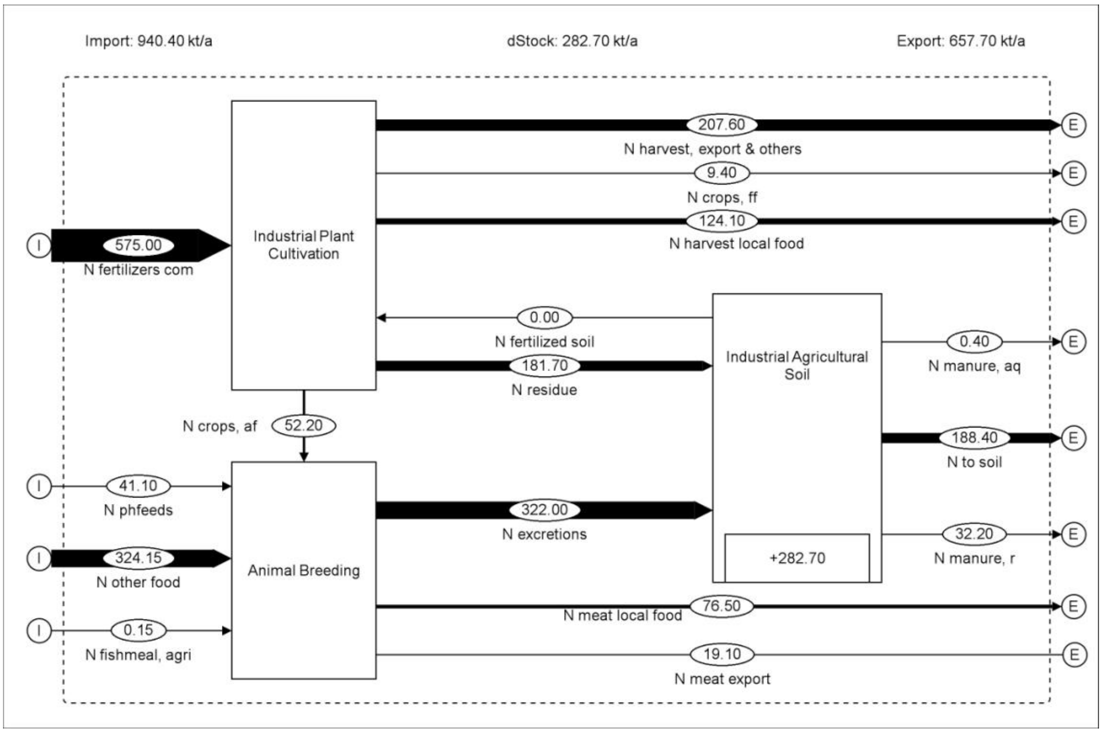
2005. In the SFA of East Indonesia, the total population of Indonesia is multiplied by 17%.

In terms of aquaculture, Indonesia had a mean production of 2.1 million tons for the years 2004-2006. Eastern Indonesia accounted for 1.1 million of these (Hoegh-Guldberg et. al., 2009). Hence in the computations, of this SFA the researcher will assume that 50% of Indonesia's total aquaculture waste that goes into marine areas will eventually reach the Coral Triangle.

C.1. Indonesia-Nitrogen Sources, Pathways and Sinks

C.1.a Indonesia-Agriculture Sub-system for Nitrogen

Figure 26. N Agriculture Sub-system, Indonesia (kt/a)



According to Indonesia's Statistics Office in 2005, Indonesia produced 89,814,754 tons of primary and secondary crops (Badan Pusat Statistik, 2012). Of these seven major crops, East Indonesia produced an estimated average of 23% of production. Hence the researcher will use 23% as the percentage of agricultural share of East Indonesia

The FAO details the amount of consumed N in fertilizers for crops as 1,657,820 tons/a in 2001 (FAOSTAT, 2001c). Nonetheless, because of the amount of harvests for 2005 the researcher is converting this 2001 value of industrial fertilizers to that of the baseline year. In Indonesia, an average of 49.6% increase per year from 1975-2002 in industrial fertilizer consumption was seen (FAO, 2005). Hence the researcher will assume this growth rate of fertilizer use to reach the 2005 baseline year but will only compute a 49.6% increase only until 2002 to account for any decrease in consumption.

N fert 2002= 1,700,000 x 0.496 + 1,700,000=2,543,200 tons/a

***N fertilizers com*= 2,500,000 tons/a**

***N fertilizers com East Indonesia*= 2,500,000 x 0.23=575,000 tons/a**

Agriculture in Indonesia, like the Philippines still plays a very important role. In 2009, 16% of GDP came from plant cultivation. Rice, the staple is a primary product with maize, soy bean, sweet potatoes and peanuts as secondary crops. In 2005, total produce from both wet and dry paddies amounted to 54.1 million tons. Nonetheless, Indonesia has other important crops such as rubber, coconut, palm oil, coffee, cocoa and tea (FAO AQUASTAT, 2012).

According to Indonesia's Statistics Office in 2005, Indonesia produced 89,814,754 tons of primary and secondary crops (Badan Pusat Statistik, 2012). Of these seven major crops, East Indonesia produced an estimated average of 23% of production. In Badan Pusat's website, the figures for vegetables produced in 2005 was 5,081,690 tons while fruits were at 14,508,432 tons and industrial crops plus crops for beverages were pegged at 15,145,594 tons (Badan Pusat Statistik, 2012). Because there are more detailed data for Indonesia the researcher is grouping primary products together as PPC1 and will use the 0.12 (*Ppc1*) crude protein used in previous computations. PPC2 will be vegetables and fruits of which 0.032 (*Ppc2*) crude protein will be used. Lastly PPC3 will be industrial crops and beverages and tobacco of which a crude protein of 0.032 (*Ppc3*) will also be used.

***Products from Plant Cultivation*=(Crq1 x Ppc1 x Npp)+(Crq2 x Ppc2 x Npp)+(Crq3 + Ppc3 x Npp)**

Where:

Crq=quantity of crop harvests per annum

Ppc1 up to Ppc3= average percentage of crude protein in crops

Npp=nitrogen percentage in protein

***PPC1*=89,000,000 tons/a x 0.12 x 0.16=1,708,800 rounded to 1,700,000 tons/a**

***PPC2*=19,000,000 tons/a x 0.032 x 0.16=97,280 rounded to 97,300 tons/a**

***PPC3*=15,000,000 tons/a x 0.032 x0.16=76,800 tons/a**

***Products from Plant Cultivation*= 1,700,000 + 97,300 + 76,800**

=1,874,100 rounded to 1,900,000 tons/a

***Products from Plant Cultivation East Indonesia*= 1,900,000 x 0.23=437,000 tons/a**

***N Crops, af* =Afq x Plf x Cap x Cpp x Npp**

Where:

Afq=quantity of total animal feeds that go into poultry, hogs and others

Plf=percentage of feeds sourced locally

Cap=percentage of total animal feeds from crops

Ccp=crude protein percentage in crops

Npp=percentage of N in protein

***N Crops, af* =6,405,000 tons/a x 0.59 x 0.95 x 0.42 x 0.16**

=227,688.55 rounded to 227,700 tons/a

***N Crops, af East Indonesia*=227,700 x 0.23= 52,210 rounded to 52,200 tons/a**

The researcher also assumed a value of 10% of the *Products of Plant Cultivation* such as rice stalks, and other plant material left on the fields and used as an organic fertilizer.

Thirty one million hectares of land in Indonesia are cultivated with 35-40% allotted for export crops such as palm oil, tobacco, coffee and tea (Encyclopedia of the Nations, 2012b). Hence, the researcher is assuming 0.375% as the percentage of total local crops to go to foreign country exports.

***N harvest export*=1,900,000 x 0.375=712,500 tons/annum**

***N harvest export (to other countries) East Indonesia*=437,000 x 0.375**

=163,875 rounded to 163,900 tons/annum

The researcher will also take into account that despite only 17% of Indonesia's total population resides in East Indonesia, 23% of the country's agriculture is done in this area. Hence, the researcher is assuming that a percentage of the food crops produced in East Indonesia is also "exported" to the rest of the country. The researcher will then assume that this is 10% of total agricultural production in East Indonesia. Hence:

N harvest export East Indonesia=N harvest export to other countries + N harvest export to other Indonesia provinces

***N harvest export East Indonesia*={163,900 tons/a + (437,000 tons/a x 0.1)}**

=207,600 tons/a

The STAN program then automatically computes for *N harvest, local food* also an input flow to the *To Nourish* sub-system

A percentage of the crops are also used as ingredients for fish feeds. This is computed in the succeeding sub-system on aquaculture and is represented by the flow *N crops, ff.*

Animal Breeding have the following input flows: *N crops af*, *N phfeeds*, *N fishmeal, agri,* and *N other food*.

Another of the input flows to *Animal Breeding* is *N, fishmeal agri* which was already computed for in the *Aquaculture* sub-system.

***N, Phfeeds*= Afq x Pmp x Cpp x Npp +Flx**

Where:

Afq=Total animal feeds consumed in Indonesia

Pmp=percentage from imported sources derived by deducting 59% (locally sourced feeds) from 100%

Cpp=crude protein percentage which is further computed by multiplying the assumed share of plant cops (95%) and fishmeal and other ingredients (5%). The value for imported fishmeal is culled from averaging fishmeal crude protein used in the chapter on the Philippines. Cpp computations for Indonesia below:

0.95 (0.42)=0.40

0.05 (0.725)=0.04

Npp= N percentage of protein

Flx=N in fish meal/trash fish from locally caught wild fish that are put into animal feeds; estimated at 5,700 tons/a. (See page 88 for computations)

***N, Phfeeds*= 6,045,000 tons/a x 0.41 x 0.44 x 0.16 +5,700**

=180,182.88 rounded to 180,200 tons/a

***N, Phfeeds Indonesia*=180,200 tons/a x 0.23=41,146 rounded to 41,100 tons/a**

An output flow from *Animal Breeding* is *N,excretions*. There are several ways to compute for this. In this study the researcher, based on the data she found based her computations on this:

N, excretions=∑ animal heads per year x N excretion per animal per year

N, excretions=(Phq x Nep) + (Hhq x Neh) + (Rhq x Ner)

Where:

Phq=number of chicken heads per annum

Nep=N excretion in kg per chicken per year

Hhq=number of pig heads per annum

Neh=N excretion in kg per pig per year

Rhq=number of cows and buffalo per annum

Ner=N excretion in kg per ruminant per year

***N, excretions*= (Phq x Nep) + (Hhq xNeh) + (Rhq +Ner)**

***N, excretions*=(1,174,933,000 x 0.52 kg) + (6,801,000 x 10.3 kg) + {(10,680,000 +2,428,000) x 53.6 kg}**

***N, excretions* =1,383,604,260 kg/a rounded to 1,400,000 tons/a**

***N, excretions East Indonesia*=1,400,000 x 0.23=322,000 tons/a**

The values for the number of heads for poultry, hogs, cattle and buffalo were based on a report of the Canadian Agri-Food Trade Service. These figures on Indonesian animal production are based on 2005 figures (Canadian Agri-Food Trade Service, 2009c). In Austria's Informative Report for Agriculture, for chicken an excretion of 0.52 kg of N per animal per year is pegged (Anderlet. al., 2008). This is the same value the researcher is using for *Nep* in this paper. Fattening pigs are at 10.3 kg of N per animal while cattle 1-2 years is pegged at 53.6 kg of N per animal per year (Anderl et. al., 2008). The value for fattening pigs represent *Neh* in this study, while the value for cattle represent *Ner*.

For the N remaining in animal meat, the researcher is basing her figures on an interview with Professor Matthias Zessner of the TU Wien who has worked on nutrient loads in the Danube. In the interview Prof. Zessner approximated that, of 100% N intake, 30% goes to pork and chicken meat while 70% goes to excretion. For beef, 15% remain with the product, while 85% goes to excretion (Zessner, 2012). The researcher then derived the N that goes to the finish product such as meat, eggs, dairy products labeled *N meat local food.*

***N meat*=∑ N in poultry produce + N in pork produce + N in cattle and buffalo**

N in poultry produce={(Phq x Nep)/0.70} x 0.30

={(1,174,933,000 x 0.52 kg) /0.70} x 0.30=261,842.21 rounded to 261,800 tons/a

N in pork produce={(Hhq xNeh)/0.70} x 0.30

={(6,801,000 x 10.3 kg)/0.70} x 0.30=30,021.56 rounded to 30,000 tons/a

N in cattle and buffalo={(Rhq +Ner)/0.85} x 0.15

{(10,680,000 +2,428,000) x 53.6 kg }/.85 x 0.15=123,986.26 rounded to 124,000 tons/a

***N meat*=415,800 tons/a**

***N meat East Indonesia*=415,800 x 0.23**

=95,634 rounded to 95,600 tons/a

The researcher is then assuming that 20% of meat is exported to other regions of Indonesia as well as to other neighboring countries. It is a fact that Singapore imports some of its meats from Indonesia.

Hence:

***N local meat East Indonesia*=95,600 x 0.80=76,480 rounded to 76,500 tons/a**

***N meat export East Indonesia*=95,600 x 0.20=19,120 rounded to 19,100 tons/a**

The difference between the inputs to *Animal Breeding* and *N excretions* is the N in meat. For this systems model, the assumption is that they all go to local food since the Indonesia has no significant meat exports but instead imports meat from Australia. This outflow *N, meat local food* also includes other products such as eggs and dairy.

Finally, the last process is *Industrial Agriculture Soil*. This process has two input flows. *N residue* is the difference between all the inputs to *Industrial Plant Cultivation* and the harvests. This will indicate whether there is excess fertilization or not. *N excretions* also go to *Industrial Agricultural Soil* and are further distributed to the *Aquaculture* sub-system as *N manure, aq* or to the process *Rivers* as *N manure, r.*

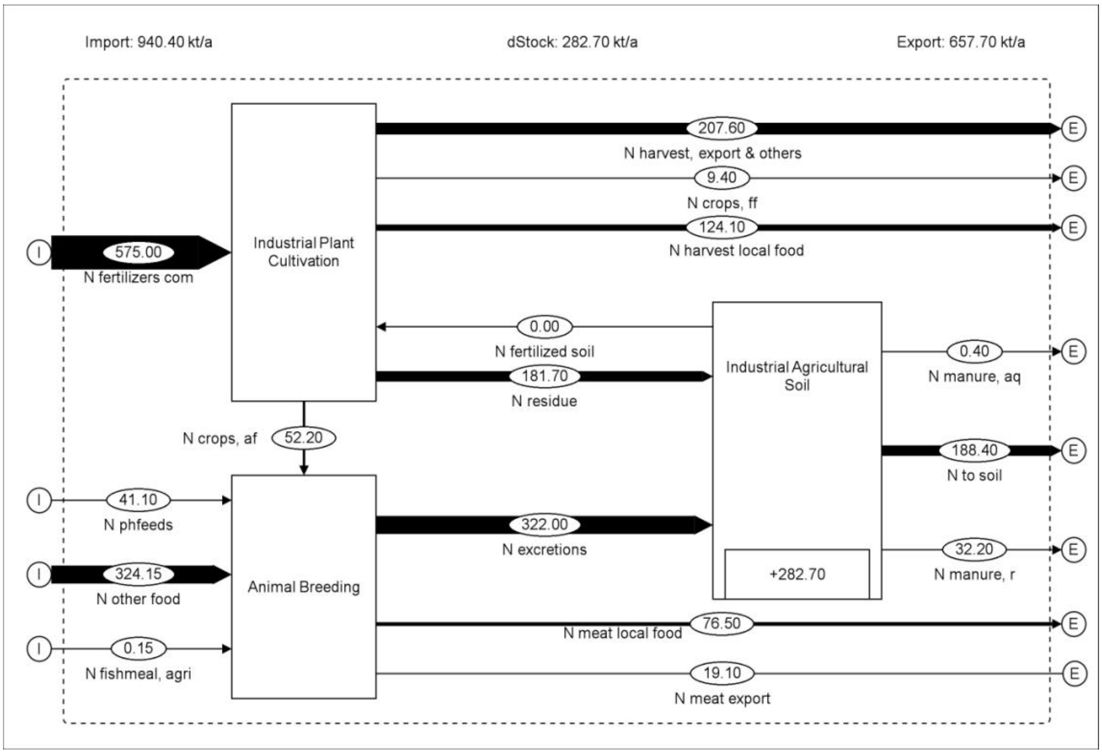
N crops ff or the plant crops that go to fish feeds will be computed in the succeeding section on Indonesia's *Aquaculture* sub-system.

C.1.b *Indonesia- Aquaculture Nitrogen Sub-system*

In terms of aquaculture, Indonesia had a mean production of 2.1 million tons for the years 2004-2006. Eastern Indonesia accounted for 1.1 million of these (Hoegh-Guldberg et. al., 2009).

Hence this study's SFA will only show 50% of Indonesia's aquaculture sector which will take into account only the portion produced by East Indonesia. The researcher is assuming that 50% of Indonesia's total aquaculture waste that goes into marine areas will eventually reach the Coral Triangle.

Figure 27. N Aquaculture Sub-system, Indonesia (kt/a)



More often than not organic fertilizers are more expensive than inorganic fertilizers in Indonesia. The reason being higher labor and transportation costs. Organic fertilizers have also been restricted in prawn farming to avoid the transmission of crustacean illnesses, although it is still used at times in semi-intensive prawn culture (Nur, 2007).

Nevertheless, it was estimated that 19,600 tons of organic fertilizers were used in 2003 (Nur, 2007). This figure will be used for the 2005 estimate as well. The researcher will also assume that like the Philippines these organic fertilizers are largely made from chicken manure.

***N manure, aq*= M x MaN**

Where:

M=amount of chicken manure from domesticated animals used by the aquaculture industry in tons/year.

MaN= percentage of N in a particular animal manure used in the aquaculture industry

***N Manure, aq*=19,600 tons x .039=764 rounded to 800 tons/a**

***N Manure, aq East Indonesia*=800 x 0.50=400 tons/a**

Aside from organic fertilizers, Indonesia makes use of inorganic fertilizers. However they use less than the inorganic fertilizer in the Philippines. According to the FAO study done by Abidin Nur in 2003, over seven thousand tons (7,600 tons) of inorganic fertilizers were used in freshwater and brackish-water pond aquaculture. Of these urea and triple super phosphate were the most commonly used inorganic fertilizers. Other fertilizers used to stimulate algal/plankton growth are SP36 (36% P_2O_5 and 5% Sulfur) and NPKS (15:15:15:10) (Nur, 2007). Since there are no exact figures, the researcher will then assume 35% of the total fertilizer consumption for both urea and TSP and 15% each for the rest.

i. Urea $CO(NH_2)_2$

C= 1 x 12.011 grams/mole=12.011 g/mol

O=1 x 15.999 g/mol=15.999 g/mol

N=2 x 14.007 g/mol=28.014 g/mol

H=4 x 1.0079 g/mol=4.0316 g/mol

Molecular mass of $CO(NH_2)_2$= 60.0556 g/mol

Proportion of N in Urea= 28.014 g/mol /60.0556 g/mol=0.4665 of 46.7%

N in Urea= 0.467 x (0.35 x 7,600 tons/a)=1242,2 rounded to 1,200 tons/annum

ii. N in NPKS-0.15 x (0.15 x 7,600 tons/a)=171 rounded to 200 tons/a

To determine the total N in algal fertilizers consumed in 2003, the total N for each of the fertilizer types are simply added:

***N algal fert*= ∑ N in Fertilizers**

***N algal fert*=1,200 tons/a + 200 tons/a = 1,400 tons/annum**

***N algal fert East Indonesia*= 1,400 x 0.50=700 tons/annum**

According to FAO, aquaculture is increasing in Indonesia with prawn farming requiring the bulk of commercial feeds. Commercial feeds rely on imported and local crops (Nur, 2007). And unlike the Philippines the FAO has made the distinction from commercial prawn farming and fish farming. Hence there is available data on these.

Indonesia is said to have the capacity to produce 12 million tons of animal feed. According to the FAO 84.5% is allotted mainly for poultry (Nur, 2007). The Canadian Agri-Food Trade Service estimates it at 80% (Canadian Agri-Food Trade Service, 2009c).

The report by Nur also estimates 595,000 tons of animal feeds consumed by the aquaculture industry. In 2005, imported feeds were pegged at 300,000 tons (Nur, 2007). Hence the researcher assumes that 295,000 are sourced within Indonesia. The Canadian Agri-Food Trade Service further estimates that of local feed production vegetable and fruit materials, rice, maize, cassava consists of 95% of local feed production (Canadian

Agri-Food Trade Service, 2009c). Hence, the researcher is assuming this same percentage in the local aqua-feed production.

N crops, ff **=(Dcf x Fpp) x Ccp x Npp**

Where:

Dch=domestic harvest for fish/crustacean feeds

Fpp=percentage of fish/crustacean feeds from plants

Ccp=crude protein percentage from said crops

Npp=N percentage in protein

N crops,ff **= (295,000 tons/a x 0.95) x 0.42 x 0.16**

=18,832.8 rounded to 18,800 tons/a

N crops,ff East Indonesia **=18,800 x 0.23=4,324 rounded to 4,300 tons/a**

=18,800 x 0.5=9,400 tons/a

According to FAO, Indonesian fish farmers prefer imported fishmeal to the local fishmeal, as the ash and lipid contents of local fishmeal are greater. This is specially applicable in farm raising prawns and carnivorous fish. Hence, in 2004 an estimated 82.39% of imported feeds were from fish, squid, meat and bone meal, 13.48% came from crops like soybean and wheat plus binders, while 2.08% was from prepared shrimp feeds (Nur, 2009).

In this sub-system *N imp feeds +fishmeal fisheries* will stand for imported fish feeds plus fishmeal from seacatch. It means the total amount of imported prepared feeds and commercial feeds manufactured from imported crops and imported fishmeal. The crude protein percentages established in the previous computations for the Philippines will be used for the following computations:

ii. *N imp feeds+fishmeal fisheries*= (Imf x Pfp x Cfp x Npp) + (Imf x Icp x Cip x Npp) + (Imf x Mfp x Aqp x Cmp x Npp) +Fax

Where:

Imf=quantity of imported fish feeds

Pfp=percentage of prepared fish feeds

Cfp=crude protein percentage from prepared fish feeds

Npp=N percentage in protein

Icp=percentage of imported crop material in Imf

Cip=crude protein percentage from imported crop materials

Mfp=percentage of imported fish meal material in Imf

Cmp= crude protein percentage from imported fish meal material.

Fax=fishmeal from trashfish caught from fisheries (wild caught) that go to aquaculture feeds

Imf x Pfp x Cfp x Npp=300,000 tons/a x 0.02 x 0.40 x 0.16

=384 to 400 tons/a

Imf x Icp x Cip x Npp= 300,000 tons/a x 0.13 x 0.42 x 0.16

=2620.8 rounded to 2,600 tons/a

Imf x Mfp x Cmp x Npp= 300,000 tons/a x 0.82 x 0.725 x 0.16

=28,536 rounded to 28,500 tons/a

Fax=739.86 rounded to 700 tons/a (See page 87 for computations)

***Imf feeds, N*= 400 tons/a + 2,600 tons/a + 28,500 tons/a +700 tons/a=32,200 tons/a**

***Imf feeds, N East Indonesia*=32,200 x 0.50=16,100 tons/a**

In the FAO report in 2004, Indonesia produced an estimated 1,468,000 tons (Nur, 2007). The WWF Coral Triangle Report listed it at 2.1 million tons (Hoegh-Guldberg et. al., 2009). Nonetheless, Nur describes this result as including the raising of seaweeds in the sea. Hence the researched added up all the estimated production of fish and crustaceans from Nur's FAO report. This totaled 1,063,000 tons of produce fed with an estimated 590,000 tons of fish feeds for the year 2005.

To compute for this flow:

***N to harvest*=Sgq x Npf**

Where:

Sfq=quantity of seafood (fish and crustacea) from aquaculture

Npf=N percentage in protein

***N to harvest*=(1,000,063 x 0.03)= 30,001.89 rounded to 30,000 tons/a**

***N to harvest East Indonesia*= 30,000 x 0.50=15,000 tons/a**

N fishmeal, ff is the output flow from *N aqua harvests* but an input flow to the first process *Aquaculture Areas*. It is computed by the following formula:

***N fish meal ff*= (Dch x Fmp x 0.05) x Clf x Npp**

The report by Nur also estimates 595,000 tons of animal feeds consumed by the aquaculture industry. In 2005, imported feeds were pegged at 300,000 tons (Nur, 2007). Hence the researcher assumes that 295,000 are sourced within Indonesia. The Canadian Agri-Food Trade Service further estimates that of local feed production vegetable and fruit materials, rice, maize, cassava consists of 95% of local feed production (Canadian

Agri-Food Trade Service, 2009c). At this point the researcher is again assuming that only 5% of the total fishmeal that goes to fish feeds comes from the aquaculture sector.

Where:

Dcf=domestic harvest for fish/crustacean feeds

Fmp=percentage of total animal feeds from local fish meal

Clf=crude protein in local fishmeal

Npp=percentage of N in protein

***N fish meal ff*={295,000 tons/a x 0.05 x 0.05} x 0.33 x 0.16**

=38.94 rounded to 40 tons/a

***N fish meal ff East Indonesia*=40 x 0.50=20 tons/a**

Fishmeal from wild caught fish that goes to aquaculture feeds or Fax={295,000 tons/a x 0.95 x 0.05} x 0.33 x 0.16=739.86 rounded to 700 tons/a

N fishmeal, agri is the output flow that comes from *Fish Biomass, Process and Distribution*. It is computed as the total share of harvests from aquaculture in the country that end up in animal feeds in agriculture. These feeds are both poultry and hog feeds. To compute for this output flow the following is the formula:

***N fishmeal, Agri*=Afq x Psl x Pfp x 0.05 x Clf x Npp**

Where:

Aqf=quantity of animal feeds that go to poultry, hogs, ruminants

Psl= percentage of locally sourced animal feeds in in Indonesia

Pfp=percentage of animal feeds from fishmeal

Clf=crude protein in local fishmeal

Npp=percentage of N in protein

In this model, the researcher is assuming that only 5% of the total fishmeal comes from aqua-cultured species. As there is no data on this, and it is assumed that the fish that go into local fishmeal are the small unused catch from both fisheries and aquaculture.

According to the Canadian Agri-Food Trade Service, Indonesia produces 20 million tons of agricultural products and their corresponding wastes used in the local animal feed industry, of which 3% is fishmeal. The report also detailed that 8% of animal feeds go to the aquaculture industry (Canadian Agri-Food Trade Service, 2009c). Nevertheless, there is no specific year given by the report on the value of agri products to animal feeds. The researcher found a value from a market research report detailing that close to every year, Indonesia has a 5-7 million ton requirement of animal feed and that its capacity as of 2005 was close to 11.3 million (Datacon, 2008). Hence the researcher is assuming that 7 million is the total production as of 2005. Because if one multiplies the percentage that the Canadian Agri-Food Trade Service value for aquaculture share of feeds (8%), one will arrive at a very close value to the 595,000 tons estimated by Nur's report as the value of total aquaculture feeds; 295,000 tons of which come from local sources (Nur, 2007). Hence, it will be safe to assume that 6,405,000 tons of animal feeds go to feeds for hogs, poultry and other domesticated terrestrial animals. Of this amount 80% goes to poultry, 7% for hogs and cattle feed is 3% and the rest goes to other feeds besides pet food (Canadian Agri-Food Trade Service, 2009c). The researcher will assume it is for other ruminants like buffalo or other domesticated fowl like ducks.

Nevertheless, from the data given, one cannot ascertain the percentage of domestic products in its contribution to the total ingredients of animal feeds produced in Indonesia. Hence the researcher will use 59% culled from the ratio of imported versus locally sourced ingredients for animal feed in Nur's report.

***N fishmeal,agri*=6,405,000 tons/a x 0.59 x 0.03 x 0.05 x 0.33 x 0.16**

=282.47 rounded to 300 tons/a

***N fishmeal, agri East Indonesia*= 300 x 0.5=150 tons/a**

Fishmeal/fish trash from local fisheries(wild caught) to go to animal feeds or Flx= 6,405,000 tons/a x 0.59 x 0.03 x 0.95 x 0.33 x 0.16=5,686.56 rounded to 5,700 tons/a

According to the FAO, in 2003 prawn exports was valued at 50% of all fisheries export (Nur, 2007). In FAO's National Aquaculture Sector Overview, it is reported that 52% of the value of fisheries export and 16% of volume comes from both fisheries and aqua-cultured shrimp in 2003. Volume increased at 6% per year arriving at an estimated volume of 137,636 tons of exported shrimp in 2003. It is also further stated that 90% of Indonesia's produce from both aquaculture and fisheries is used domestically (FAO AQUASTAT, 2012). Looking at Nur's report 90,000 tons of tiger shrimps were produced in 2005. Based on the researcher's experience in the aquaculture industry tiger shrimps in Southeast Asia are raised purely for export to Japan, Singapore, the U.S. and other highly industrialized countries. Hence the researcher will add this value to 30 tons of tilapia exported to the U.S. In Nur's FAO report an estimated 40 tons of tilapia in 2000 and close to 30 tons in 2001 was exported by Indonesia to the U.S. (Nur, 2007).

Hence to achieve the export rate: 90,000 tons of tiger shrimp + 30 tons of tilapia/ 1,000,063 of aquaculture produce=.09 or 9%

***N fish export*= 93,000 tons/a x 0.09**

=8,370 rounded to 8,400 tons/a

***N fish export East Indonesia*= 8,400 x 0.50=4,200 tons/a**

N fish, local food is then automatically computed by the STAN program.

***N fish excr*=Sfq x Enf**

Where:

Sfq=quantity of seafood (fish and crustacea) from aquaculture

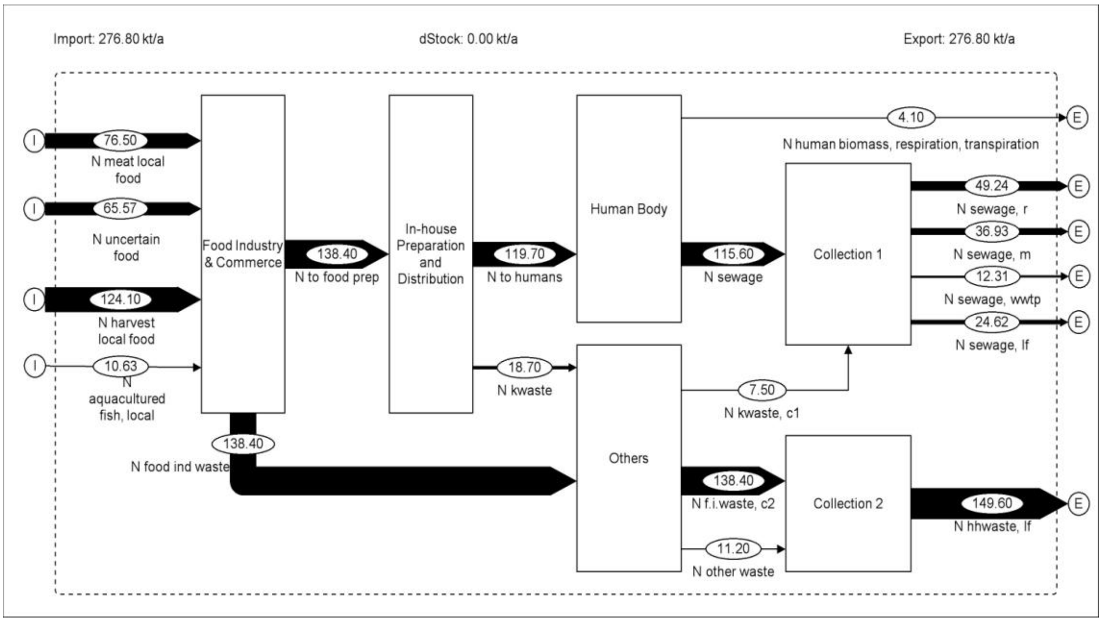
Enf=percentage of N excretion for every ton of fish

***N fish excr=* 1,000,063 tons/a x .051 =51,003.2 rounded to 51,000 tons/a**

***N fish excr East Indonesia*=51,000 x 0.50=25,500 tons/a**

C.1.c Indonesia-To Nourish Sub-system for Nitrogen

Figure 28. N To Nourish Sub-system, Indonesia (kt/a)



To compute for the N intake of the Indonesia, an input (*N to humans*) is fed into the process *Human Body*. Like mentioned in the preview on Indonesia, an estimated 17% of Indonesia's population lives in East Indonesia. Hence, to estimate East Indonesia's contribution 17% is multiplied to the total population of the whole country.

***N to humans*=Po x IntN**

Where:

Po=population

IntN=per capita intake of N per year

N to humans= (220,000,000 +16,300) x 3200 grams/annum

***N to humans Indonesia*=704,000 tons/annum**

***N to humans East Indonesia*= {(220,000,000 x 0.17) + 16,300 x 3200 grams/a }**

= 119,732 rounded to 119,700 tons/annum

The data for Nitrogen per capita/annum of 3200 g was culled from the book "Metabolism of the Anthroposphere."

The N from inedible and edible kitchen waste is represented by another flow of which the values of Nks and Nkg were also culled from Baccini and Brunner's Metabolism of the Anthroposphere.

***N kwaste*=Po (Nks + Nkg)**

Where:

Po=population

Nks=per capita N from kitchen waste that goes to sewage

Nkg=per capita N from kitchen waste that goes to garbage

N kwaste= 220,000,000 (200 grams/annum + 300 grams/annum)

N kwaste =(44,000 tons/annum + 66,000 tons/annum)

***Nkwaste Indonesia*=110,000 tons/annum**

N kwaste East Indonesia =(44,000 tons/annum x 0.17 + 66,000 tons/annum x 0.17)

N kwaste East Indonesia =(7,480 tons/annum + 11,220 tons/annum)

***N kwaste East Indonesia*=(7,500 tons/annum + 11,200 tons/annum)=18,700 tons/a**

***N kwaste, c1 East Indonesia*=7,500 tons/a**

***N to other waste East Indonesia*=11,200 tons/a**

The above N intake is only what the population consumes. Food products from the food industry go through processing thereby producing waste. According to Prof. Brunner, an estimated amount equal to food consumption goes to industrial food processing and food commerce waste before even reaching household kitchens (Brunner, 2012). The SFA above computes for this. Thus, *N to food prep* and *N ind waste* have the same values: the sum of *N to humans* and *N kwaste.*

The rest of the N that does not go to sewage is the sum of what is retained by the human body and then transpired and respired. Out of the 3,000g per capita/annum, 2600 grams of N go to urine and 490 g of N go to feces (Baccini and Brunner, p.88)

To compute for the outflow *N sewage* this is the formula:

***N Sewage*=Po (UrN + FcN)**

Where:

Po= estimated population

UrN=amount of N a human urinates per annum

FcN=amount of N a human excretes (solid wastes) per annum

N Sewage=220,000,000 (2600 + 490)

***N Sewage Indonesia*=679,800 tons/annum**

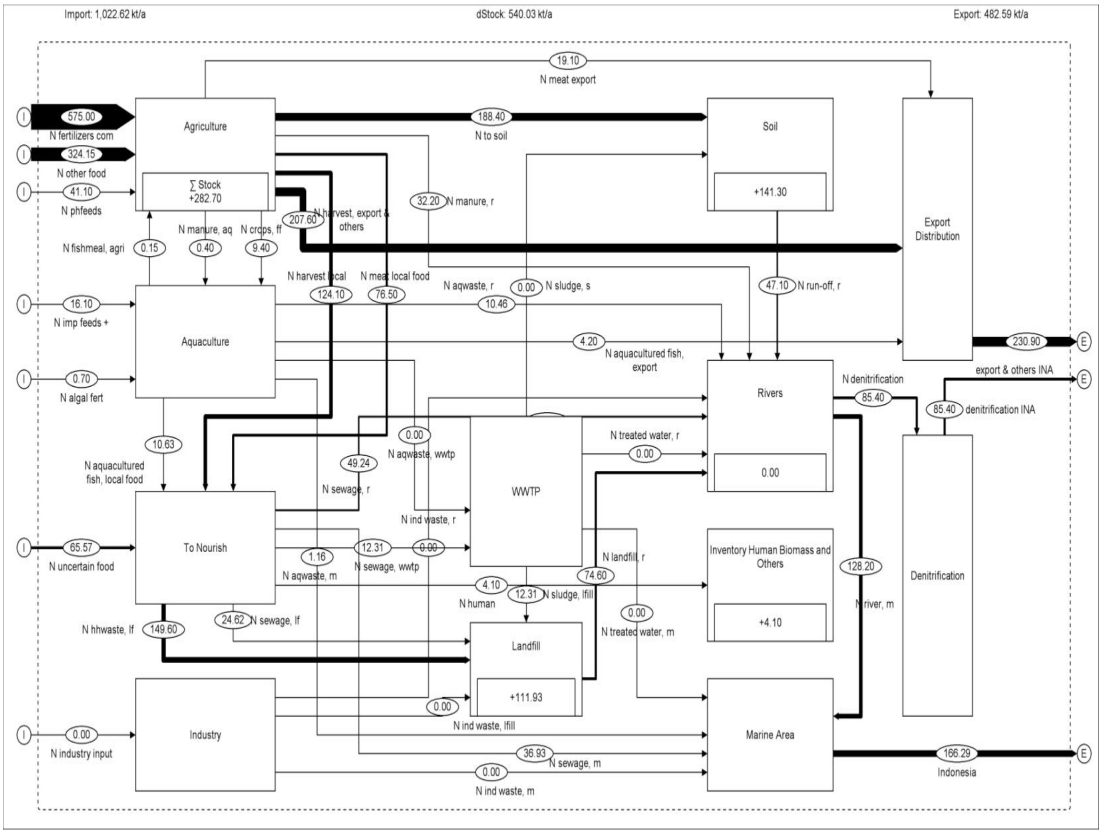
***N Sewage East Indonesia*=679,800 x 0.17 tons/annum**

=115,566 rounded to 115,600 tons/annum

N sewage then enters another process called *Collection 1*. The outflow of *Collection 1* are the following: *N sewage, r* (this goes to the process *River* in the country sub-system); *N sewage, marine* (going to the process *Marine Area*) and *N sewage, wwtp* (theoretically going to a sewage and wastewater treatment plant). In this model, the researcher is assuming transfer coefficients. In a USAID study it is mentioned that there are 10 waste water treatment plants in Indonesia, of which two are found in the island of Kalimantan while a number are located in West Indonesia (USAID, 2006). Certainly this is not enough to properly service a huge archipelago. The researcher is concluding that even the sludge of septic tanks are either placed in a landfill without treatment or dumped in rivers and waterways. The researcher is also taking into consideration the number of villages which do not have spetic tanks and hence dispose of their sewage directly at sea. Hence the transfer coefficients assumed in this study is approximately 40% for *N sewage, r*; 30% for *N sewage, m*; 10% for *N sewage, wwtp* and 20% for *N sewage, lf*.

C.1.d Indonesia-Country Sub-system for Nitrogen

Figure 29. N Country Sub-system, Indonesia (kt/a)



(See Annex 5 for a full-page diagram)

Among the numerous inflows to *Landfill*, *Industry* is pegged at zero due to the scope and limitations of the study. The rest however, such as *WWTP* is existent. Although wastewater treatment plants in Indonesia are few and far between, it is a good start for the country to employ this intervention. The researcher is assuming that all the sludge from the *WWTP* is discarded and deposited in *Landfills*. *Nhwaste, lf* does not only include household wastes but also wastes from the food industry hence it is the biggest load with 149.60 kt of N/a to *Landfills*. Lastly, 24.62 kt of N/a come from sewage that is not treated. And although according to Professor Fellner, Indonesia has begun to establish secured landfills, the leachate is still mostly untreated and discharged to rivers (Fellner, 2012). Like in other country sub-systems it is assumed that of N% content of household waste in landfills, 60% go to stock while 40% go to leachate (Brunner, et.al., 2001).

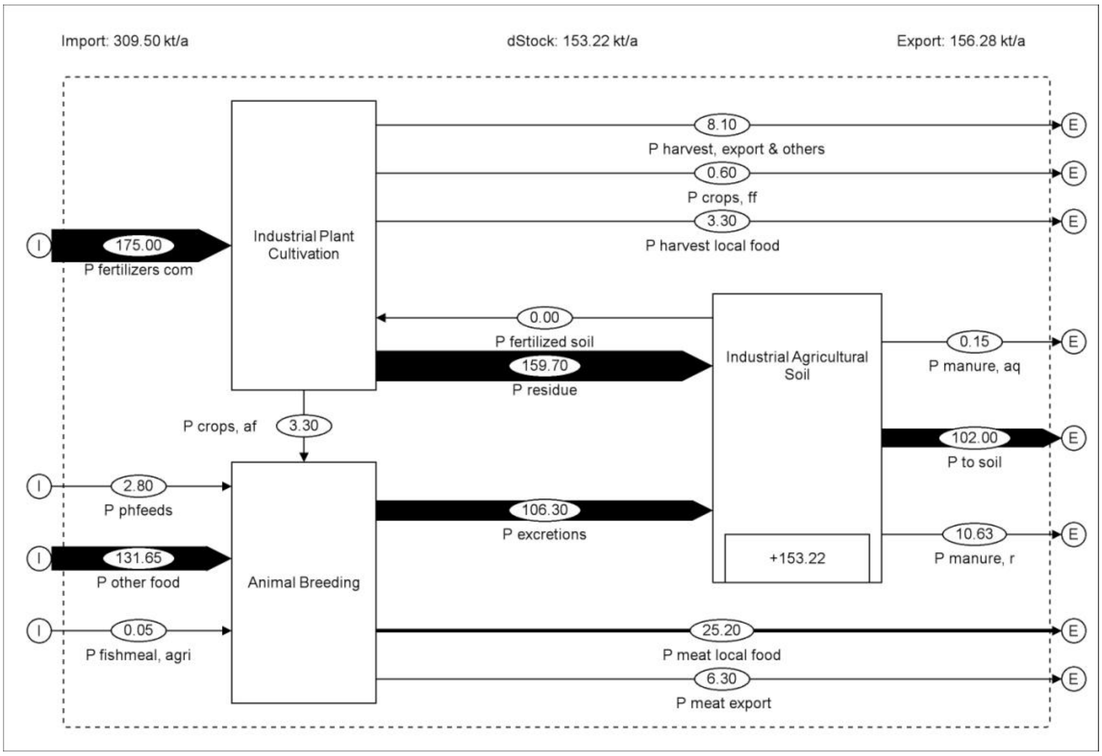
The process Soil has an input flow from Industrial Agricultural Soil. From the N that goes to Soil, a run-off of 25% of the total N is represented by the flow *N run-off, r*. Rivers have two output flows: 40% are denitrified an estimate suggested by Prof.

Zessner (Zessner, 2012) while 60% is estimated to find their way into Indonesia's *Marine Area* with a load of 166,290 tons or 166.29 kilo tons of N/annum.

C.2. Indonesia-Phosphorus Sources, Pathways and Sinks

C.2.a. Indonesia-Agriculture Phosphorus Sub-system

Figure 30. P Agriculture Sub-system, Indonesia (kt/a)



The FAO details the amount of consumed P in fertilizers for crops as 508,530 tons/a in 2001 (FAO 2012c). Nonetheless, because of the amount of harvests for 2005 the researcher is converting this 2001 value of industrial fertilizers to that of the baseline year. In Indonesia, an average of 49.6% increase per year from 1975-2002 in industrial fertilizer consumption was seen (FAO, 2005). Hence the researcher will assume this growth rate of fertilizer use to reach the 2005 baseline year but will only compute a 49.6% increase until 2002 to account for any decrease in consumption.

P fert 2002= 508,500 x 0.496 + 508,500=760,716 rounded to 761,000 tons/a

***P fertilizers com*= 761,000 tons/a**

***P fertilizers East Indonesia*= 761,000 x 0.23 =175,030 rounded to 175,000 tons/a**

***Products from Plant Cultivation*=Crq x Pcr**

Where:

Crq=quantity of crop harvests per annum

Pcr= P percentage in crops

***PPC1*=89,000,000 tons/a**

***PPC2*=19,000,000 tons/a**

***PPC3*=15,000,000 tons/a**

***Products from Plant Cultivation*= 123,000,000 x 0.0006**

=73,800 tons/a

***Products from Plant Cultivation East Indonesia*= 73,800 x 0.23**

=16,974 rounded to 17,000 tons/a

***P Crops, af* =Afq x Plf x Cap x Pfc**

Where:

Afq=quantity of total animal feeds that go into poultry, hogs and others

Plf=percentage of feeds sourced locally

Cap=percentage of total animal feeds from crops

Pfc=P percentage in feed from crops

***P Crops, af* =6,405,000 tons/a x 0.59 x 0.95 x 0.004**

=14,360 rounded to 14,300 tons/a

***P Crops, af East Indonesia*=14,300 x 0.23= 3,289 rounded to 3,300 tons/a**

The researcher also assumed a value of 10% of the *Products of Plant Cultivation* such as rice stalks, and other plant material left on the fields and used as an organic fertilizer. Thirty one million hectares of land in Indonesia are cultivated with 35-40% allotted for export crops (Encyclopedia of the Nations, 2012b) Most of Indonesia's export consists of crops like rubber, coffee, tea, cocoa. Hence, the researcher is assuming .375% as the percentage of local crops going to export. Most of Indonesia's export consists of crops like rubber, coffee, tea, cocoa.

***P harvest export*=73,800 x 0.375=27,675 rounded to 27,700 tons/annum**

***P harvest export (to other countries) East Indonesia*= 17,000 x 0.375**

=6,375 rounded to 6,400 tons/annum

The researcher will also take into account that despite only 17% of Indonesia's total population resides in East Indonesia, 23% of the country's agriculture is done in this area. Hence, the researcher is assuming that a percentage of the crops produced in East Indonesia is "exported" to the rest of the country. The researcher will then assume that this is 10% of total agricultural production in East Indonesia. Hence:

P harvest export East Indonesia=P harvest export to other countries + P harvest export to other Indonesia provinces

***P harvest export East Indonesia*={6,400 tons/a + (17,000/a x 0.10)}**

=8,100 tons/a

The STAN program then automatically computes for *N harvest, local food* also an input flow to the *Households* sub-system

***P, Phfeeds=* Afq x Pmp x Pfc +Pfn**

Where:

Afq=Total animal feeds consumed in Indonesia

Pmp=percentage from imported sources derived by deducting 59% (locally sourced feeds) from 100%

Pfc= P percentage in feed from crops

Pfn= Trash fish from local wild catch that go to animal feeds

Pfn=2,444.79 rounded to 2,400 tons/a (See page 101 for computations.)

***P, Phfeeds*= 6,045,000 tons/a x 0.41 x 0.004 +2,400 tons/a**

=12,313.8 rounded to 12,300 tons/a

***P, Phfeeds Indonesia*=12,300 tons/a x 0.23=2,829 rounded to 2,800 tons/a**

An output flow from *Animal Breeding* is *P,excretions*. In this study the researcher, will be basing her data on a ratio of N:P found in the inputs of feed, as P is determined by the diet of the animal. The ration used in the other chapter was 1:0.33. As the amount of N in previous computations also depended on the input and excretion of substances, the values for *P local meat* will also be *N local meat* multiplied by 0.33.

P, excretions=*N excretions* x 0.33

***P, excretions* =1,400,000 tons/a x 0.33=462,000 tons/a**

***P, excretions East Indonesia*=322,000 tons/a x 0.33**

=106,260 rounded to 106,300 tons/a

***P, meat local food= N meat local food* x 0.33**

***P meat*=415,800 tons/a x 0.33=137,214 rounded to 137,200 tons/a**

***P meat East Indonesia*=95,600 tons/a x 0.33**

=31,548 rounded to 31,500 tons/a

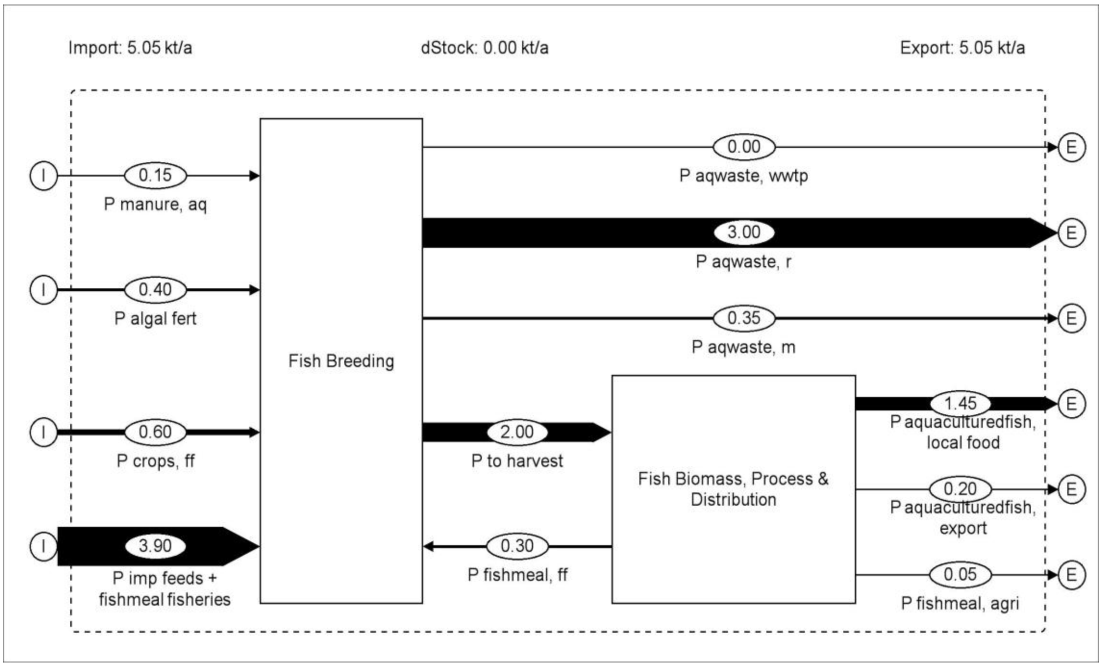
The researcher is then assuming that 20% of meat is exported to other regions of Indonesia as well as to other neighboring countries. It is a fact that Singapore imports some of its meats from Indonesia.

***P meat export East Indonesia*=31,500 x 0.2=6,300 tons/a**

***P local food East Indonesia*=31,500 x 0.8=25,200 tons/a**

C.2.b Indonesia- Aquaculture Phosphorus Sub-system

Figure 31. P Aquaculture Sub-system, Indonesia (kt/a)



***P manure, aq*= M x MaP x Proportion of P in P_2O_5**

Where:

M=amount of chicken manure from domesticated animals used by the aquaculture industry in tons/year.

MaP= percentage of P_2O_5 in a particular animal manure used in the aquaculture industry

***P Manure, aq*=19,600 tons x 0.037 x 0.436=316.2 rounded to 300 tons/annum**

***P manure, aq East Indonesia*=300 x 0.50=150 tons/a**

Commercial Algal Fertilizers

Aside from organic fertilizers, Indonesia makes use of inorganic fertilizers. However they use less than the inorganic fertilizer in the Philippines. According to FAO study done by Abidin Nur in 2003, over seven thousand (7,600) tons of inorganic fertilizers were used in freshwater and brackish-water pond aquaculture. Of these urea and triple super phosphate were the most commonly used inorganic fertilizers. Other fertilizers used to stimulate algal/plankton growth are SP36 (36% P_2O_5 and 5% Sulfur) and NPKS (15:15:15:10) (Nur, 2007). Since there are no exact figures, the researcher will then assume 35% of the total fertilizer consumption for both urea and TSP and 15% each for the rest.

i. Triple Super Phosphate $3Ca(H_2PO_4)_2$

Ca=3 x 40.078 grams/mole=120.234 g/mol

H=4 x 1.0079 g/mol=4.0316 g/mol

P=2 x 30.974 g/mol=61.948 g/mol

O=8 x 15.999 g/mol=127.992 g/mol

Molecular mass of $3Ca(H_2PO_4)_2$= 314.2056 g/mol

Proportion of P in $3Ca(H_2PO_4)_2$= 61.948g/mol/314.2056 g/mol=0.1972 of 19.7%

P in $3Ca(H_2PO_4)_2$= 0.197 x (0.35 x 7,600 tons/a)=524.02 rounded to 500 tons/annum

ii. P_20_5 in SP36-0.36 x (0.15 x 7,600)=410.4 rounded to 400 tons/a

P in P_2O_5 of SP36= 400 x 0.436=174.4 rounded to 200 tons/a

iii. P_20_5 in NPKS- 0.15 x (0.15 x 7,600 tons/a)=171 tons/a

P in P_20_5 in NPKS= 171 x 0.436=74.6 rounded to 100 tons/a

To determine the total P in algal fertilizers consumed in 2003, the total N for each of the fertilizer types are simply added:

***P algal fert*= ∑ N in Fertilizers**

***P algal fert*=500 tons/a + 200 tons/a + 100 tons/a = 800 tons/annum**

***P algal fert East Indonesia*= 800 x 0.50=400 tons/annum**

According to FAO, aquaculture is increasing in Indonesia with prawn farming requiring the bulk of commercial feeds. Commercial feeds rely on imported and local crops (Nur, 2007). And unlike the Philippines the FAO has made the distinction from commercial prawn farming and fish farming. Hence there is available data on these.

Indonesia is said to have the capacity to produce 12 million tons of animal feed. According to the FAO 84.5% is allotted mainly for poultry (Nur, 2007). The Canadian Agri-Food Trade Service estimates it at 80% (Canadian Agri-Food Trade Service 2009c).

The report by Nur also estimates 595,000 tons of animal feeds consumed by the aquaculture industry. In 2005, imported feeds were pegged at 300,000 tons (Nur, 2007). Hence the researcher assumes that 295,000 are sourced within Indonesia. The Canadian Agri-Food Trade Service further estimates that of local feed production; vegetable and fruit materials, rice, maize, cassava are 95% of local feed production (Canadian Agri-Food Trade Service, 2009c). Hence, the researcher is assuming this same percentage in the local aqua-feed production.

***P crops, ff* =Dcf x 0.95 x Pfc**

Where:

Dch=domestic harvest for fish/crustacean allotted for aquaculture feeds

Pfc=P percentage in feeds from crops

***P crops,ff*= 295,000 tons/a x 0.95 x 0.004**

=1,121 rounded to 1,200 tons/a

***P crops,ff East Indonesia*=1,200 tons x 0.50= 600 tons/a**

According to FAO, Indonesian fish farmers prefer imported fishmeal to the local fishmeal, as the ash and lipid contents of local fishmeal are greater. This is specially applicable in farm raising prawns and carnivorous fish. Hence, in 2004 an estimated 82.39% of imported feeds were from fish, squid, meat and bone meal, 13.48% came from crops like soybean and wheat plus binders, while 2.08% was from prepared shrimp feeds (Nur, 2009).

***P imp feeds+fishfeed fisheries*= (Imf x Pfp x Ppp) + (Imf x Icp x Pfc) + (Imf x Mfp x Pmp)+ Pfj**

Imf=quantity of imported fish feeds

Pfp=percentage of prepared fish feeds

Ppp=P percentage prepared pellet feeds (This considers the 2% share of prawn or shrimp feeds. The P percentage is culled from Tacon's P percentage in prawn feeds in the Chapter on the Philippines).

Icp=percentage of imported crop material in Imf

Pfc=P percentage for feeds from crops

Mfp=percentage of imported fish meal in Imf

Pmp= P percentage from imported fishmeal material.

Pfj=Local wildcaught trashfish that go to aquaculture feeds.

(Imf x Pfp x Ppp) =300,000 tons/a x 0.02 x 0.0102

=156 to 200 tons/a

(Imf x Icp x Pfc) = 300,000 tons/a x 0.13 x 0.004

=984 rounded to 1,000 tons/a

(Imf x Mfp x Pmp)= 300,000 tons/a x 0.82 x 0.0227

=5,584.2 rounded to 5,600 tons/a

Pfj=1,078.3 rounded to 1,000 tons/a (See page 100 for computations)

***P Imp feed+ffs*= 200 tons/a + 1,000 tons/a + 5,600 tons/a+1,000 tons/a=7,800 tons/a**

***P Imp feeds+ff, East Indonesia*=7,800 x 0.50=3,900 tons/a**

In the computations for

***P to harvest*=Sgq x Pff**

Where:

Sfq=quantity of seafood (fish and crustacea) from aquaculture

Pff=P percentage in fish

***P to harvest*=1,000,063 x 0.004=4,000.25 rounded to 4,000 tons/a**

***P to harvest East Indonesia*= 4,000 x 0.50=2,000 tons/a**

N fishmeal, ff is the output flow from *N aqua harvests* but an input flow to the first process *Aquaculture Areas*. It is computed by the following formula:

***P fish meal ff*= (Dch x Fmp x 0.05) x Pmp**

Like in the previous section it is mentioned that 95% of fish feeds from local material come from plant material hence the researcher is assuming that 5% comes from local fishmeal. There are no figures how much fishmeal comes from aquaculture so the researcher will use 5% as this was the same assumption in the case of Indonesia wherein most aqua-cultured fish are high value species. Since there are no values of P percentage for local fishmeal to be found, the researcher is using the value of P in imported fishmeal used in previous computations.

Where:

Dcf=domestic harvest for fish/crustacean feeds

Fmp=percentage of total animal feeds from local fish meal

Pmp=P percentage in fishmeal

***P fish meal ff*={1,000,063 tons/a x 0.05 x 0.05} x 0.0227**

=56.75 tons rounded to 60 tons/a

***P fish meal ff East Indonesia*=60 x 0.50=30 tons/a**

Local wildcaught trashfish that go to aquaculture feeds/Pfj={1,000,063 tons/a x 0.05 x 0.95} x 0.0227=1,078.3 rounded to 1,000 tons/a

***P fishmeal, Agri*=Afq x Psl x Pfp x 0.05 x Pmp**

Where:

Aqf=quantity of animal feeds that go to poultry, hogs, ruminants

Psl= percentage of locally sourced animal feeds in in Indonesia

Pfp=percentage of animal feeds from fishmeal

Pmp=percentage of P in local and imported fishmeal

In this model, the researcher is assuming that only 5% of the total fishmeal comes from aqua-cultured species. As there is no data on this, and it is assumed that the fish that go into local fishmeal are the small unused catch from both fisheries and aquaculture. As with N the *P fishmeal, agri* follows the equation use in *N fishmeal, agri* except for the use of the P percentage instead of the crude protein and N percentage.

***P fishmeal,agri*=6,405,000 tons/a x 0.59 x 0.03 x 0.05 x 0.0227**

=128.67 rounded to 100 tons/a

***P fishmeal, agri East Indonesia*= 100 x 0.5=50 tons/a**

Trash fish from wild catch that go to animal feeds/Pfn=6,405,000 tons/a x 0.59 x 0.03 x 0.95 x 0.0227=2,444.79 rounded to 2,400 tons/a

Following the scheme for estimations of export in the N *Aquaculture* Section. The computations are as follows:

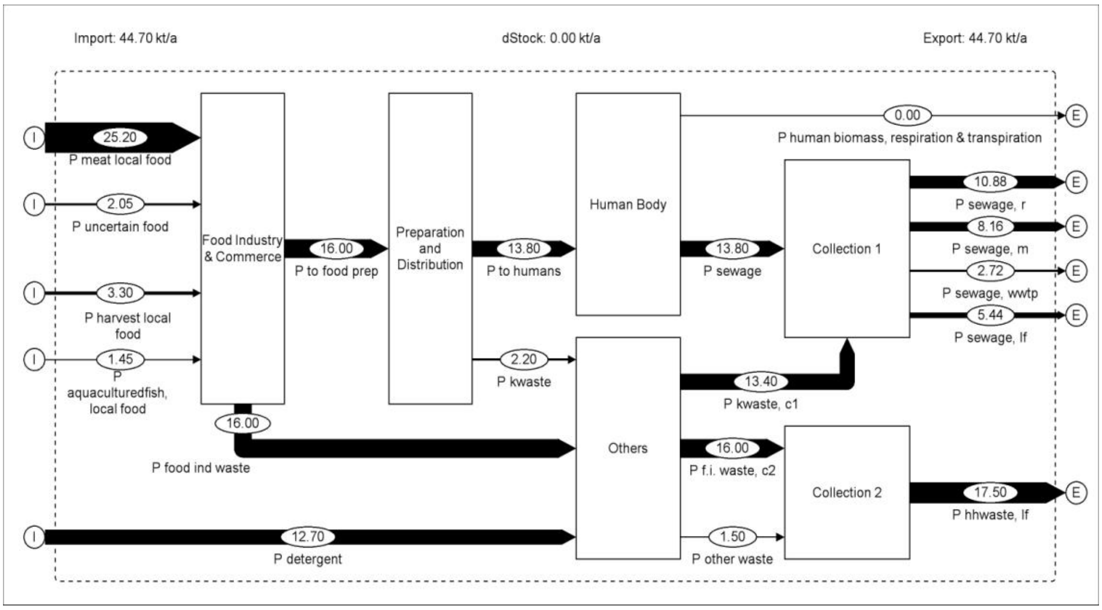
***P fish export*= 4,000 tons/a x 0.09**

=360 rounded to 400 tons/a

***P fish export East Indonesia*= 400 x 0.50=200 tons/a**

C.2.c Indonesia-To Nourish Sub-system for Phosphorus

Figure 32. P To Nourish Sub-system, Indonesia (kt/a)



Input flows to *Food Industry & Commerce* come from other sub-systems. It is only *P uncertain food* that is computed by the SFA based on the said input flows and *P to food prep*. *P to food prep* is the sum of *P to humans* and *P kwaste* computations discussed below and based on Baccini and Brunner's "Metabolism of the Anthroposphere."

To compute for the P intake of the Indonesia, an input (*P to humans*) is fed into the process *Human Body*. Basically this is the edible portion ingested by the human body:

***P to humans*=Po x IntP**

Where:

Po=population

IntP=per capita intake of P per year

P to humans= 220,000,000 x 370 grams/annum

***P to humans Indonesia*=81,400 tons/annum**

***P to humans East Indonesia=* 81,400 x 0.17**

=13,838 rounded to 13,800 tons/annum

The data for Phosphorus per capita/annum of 370 g was culled from the book Metabolism of the Anthroposphere. Out of the 370 g per capita/annum, 270 grams of P go to urine and 100 g of P go to feces (Baccini and Brunner, 1991).

To compute for the outflow *P sewage* this is the formula:

***P Sewage*=Po (UrP + FcP)**

Where:

Po=population

UrN=amount of N a human urinates per annum

FcN=amount of N a human excretes (solid wastes) per annum

P Sewage=220,000,000 (270 + 100)

P Sewage= 59,400 + 22,000

***P Sewage*= 81,400 tons/annum**

***P Sewage East Indonesia*=81,400 x 0.17**

=13,838 rounded to 13,800 tons/annum

The body does not retain nor respire and transpire any Phosphorus (Baccini and Brunner, 1991). Hence the outflow from the *Human Body* to *human brt* (biomass, respiration, transpiration) is 0.

The P from inedible and edible kitchen waste is represented by another flow.

***P kwaste*=Po (Pks + Pkg)**

Where:

Po=population

Pks=per capita P from kitchen waste that goes to sewage

Pkg=per capita P from kitchen waste that goes to garbage

P kwaste= 220,000,000 (20 grams/annum + 40 grams/annum)

***P kwaste* =(4,400 tons/annum + 8,800 tons/annum)**

***Pkwaste Indonesia*=13,200 tons/annum**

P kwaste East Indonesia =(4,400 x 0.17 + 8,800 x 0.17)

***P kwaste East Indonesia* =748 + 1496=rounded to 700 + 1,500=2,200 tons/a**

***P other waste East Indonesia*=1500 tons/a**

Two 516,000 tons of detergents were used in Indonesia in 1996. Detergents in Southeast Asia contain 30% surfactants of phosphates (Satsuki, 1999). Therefore we will assume a per capita detergent consumption by dividing the consumption by the population of Indonesia in 1996. In 1996 the estimated population was 198,320,000 (Indexmundi, 2012c) rounded to 198,000,000.

Per capita consumption of detergent=516,000 tons/198,000,000=2.6 kg per capita/annum of detergent.

Detergent consumption as of 2005= 220,000,000 x 2.6 kg=572,000 tons of detergent.

Percentage of phosphate= 572,000 x .30= 171,600 tons of phosphate

Percentage of P=171,600 x 0.436=74,817.6 rounded to 74,800 tons of P/annum

Percentage of P East Indonesia= 74,800 x 0.17=12,716 rounded to 12,700 tons/annum

***P detergent East Indonesia*=12,700 tons/a**

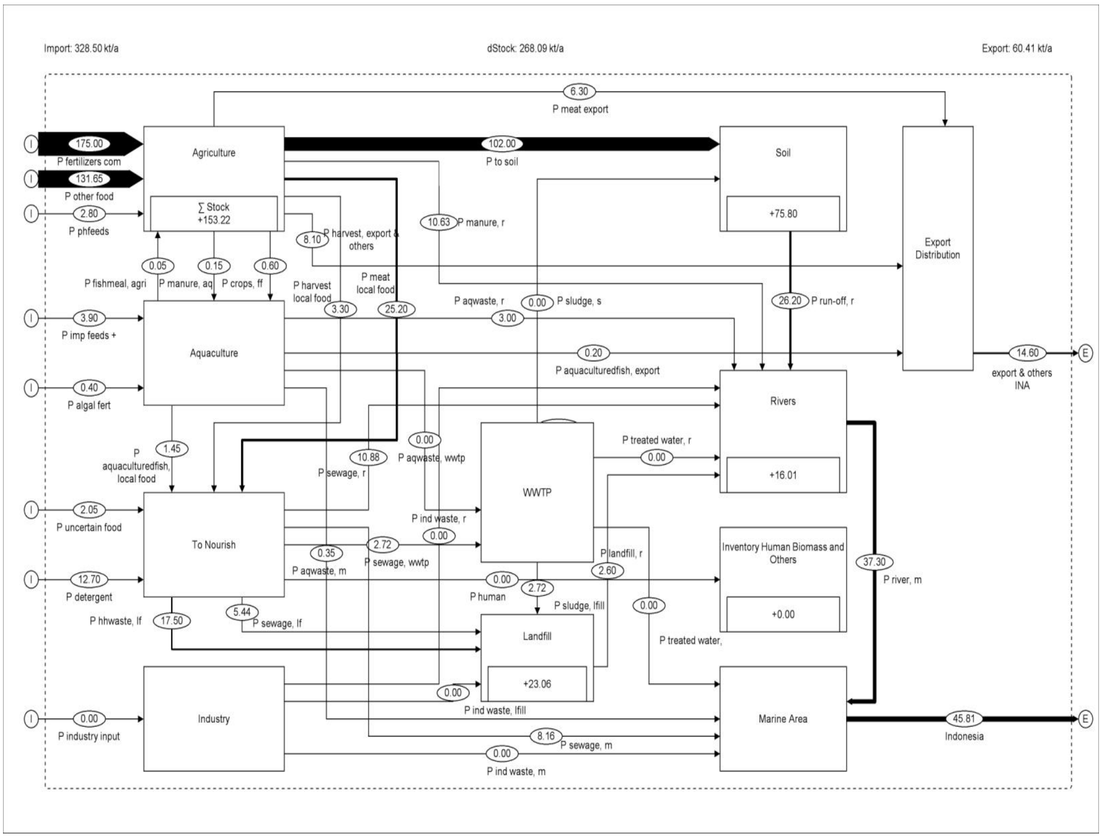
P kwaste, c1 East Indonesia=(P kwaste East Indonesia – P other waste East Indonesia)+ P detergent

***P kwaste, c1 East Indonesia*=(2,200 tons-1,500 tons)+12,700=13,400 tons/a**

Following the scheme in the N SFA of Indonesia, the transfer coefficients for Collection 1 assumed in this study is approximately 40% for *P sewage, r*; 30% for *P sewage, m*; 10% for *P sewage, wwtp;* and 20% for *P sewage, lf.*

C.2.d Indonesia-Country Sub-system for Phosphorus

Figure 33. P Country Sub-system, Indonesia (kt/a) *(See Annex 6 for full-page diagram)*



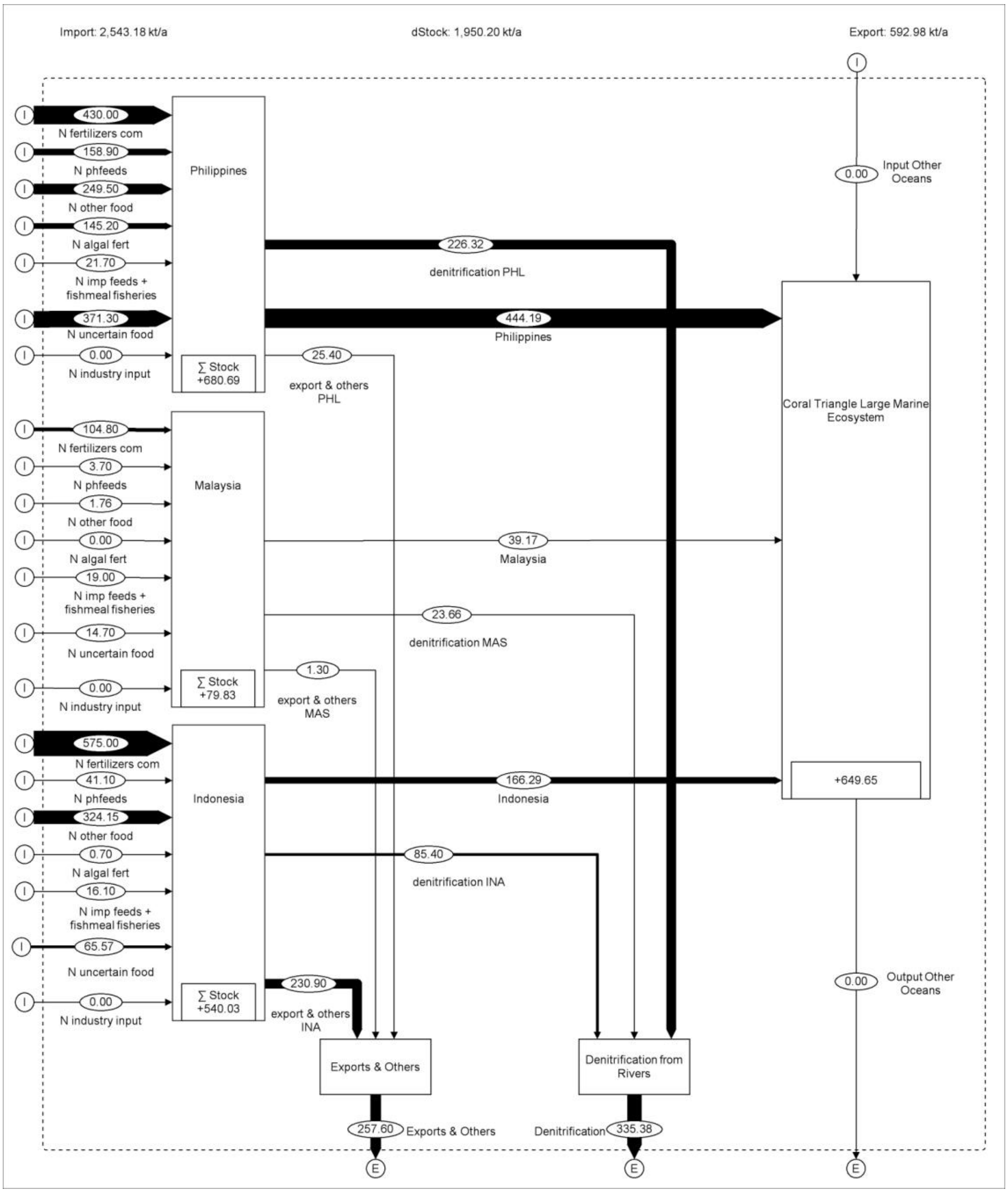
Like the N SFA on Indonesia, one flow to *Landfills* is from *WWTP*. All the sludge from the *WWTP* flows into *Landfills* estimated 2.72 kilo tons of P/annum. Some flows to Landfills include P from sewage (5.44 kt/a) and P from household waste and food industry and commerce waste (17.5 kt). It is then assumed that of this P% content of waste in landfills, 90% goes to stock while, 10% goes to leachate. These figures are based on a 2001 study by for the Environmental Federal Office, Vienna (Brunner et. al. 2001). Because the Indonesia has no treatment of leachate in its landfills it is assumed that all of the P in leachate is passed on to the rivers.

The sub-system *Soil* has an estimated run-off of 25% totaling 28.2 kt P/annum that reaches *Rivers*. P from manure in *Agriculture* as well as *Aquaculture* waste water and *P sewage* contribute to the P load in *Rivers*. Of the P load in Rivers it is assumed that 70% is passed on to *Marine Areas* while 30% is retained as stock. An assumption of 90% to *Marine Areas* will yield a difference of 10.6 kt of P/annum compared to the 70% assumed in the SFA. Finally, the P load to *Marine Areas* is 45.81 kt or 45,810 tons of P/annum also the P load of Indonesia to the CTLME

D. The Coral Triangle as a Sink for N and P

D.1. Nitrogen

Figure 34. N Overview, CTLME (kt/a)



Per capita N contribution of Philippines to CTLME

=*226,320 tons of N*/85,500,000

=0.0026 tons of N/a/capita or *2.6 kg of N/a/capita*

Although the Philippines has the highest N load as a whole to the CTLME and drastic measures and intervention need be done to curb pollution, it has the lowest per capita N load to the CTLME.

Per capita N contribution of Malaysia* **to CTLME**

=*39,170 tons of N*/3,000,000

=0.0130 tons of N/a/capita or *13 kg of N/a/capita*

*Contribution of Malaysia to the CTLME is based only on the state of Sabah.

Although Malaysia as a whole has the smallest N load to the Coral Triangle, per capita it has the biggest, partly due to the fact that a lot of industrial crop exports such as oil palm are grown in Sabah. Oil palm uses the most fertilizers which leach into the soil.

Per capita N contribution of Indonesia** **to CTLME**

=*166,290 tons of N*/(220,000,000x0.17)

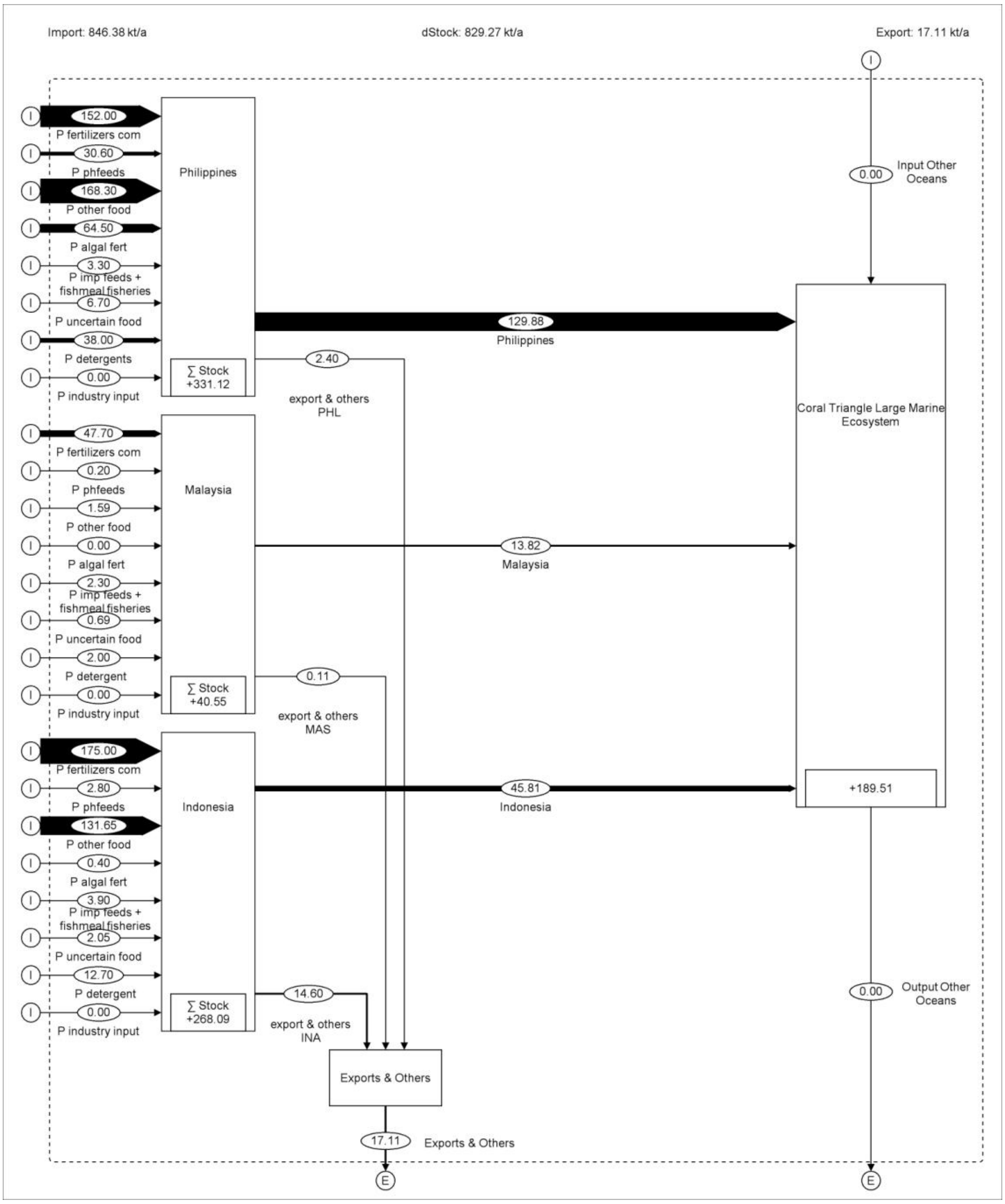
=0.0044 tons of N/a/capita or *4.4 kg of N/a/capita*

**Contribution of Indonesia is 17% of its total population; East Indonesia's total population.

The CTLME then has a yearly stock of 649.65 kt of N or 649,650 tons of N coming from the above ASEAN countries

D.2. Phosphorus

Figure 35. P Overview, CTLME (kt/a)



Per capita P contribution of Philippines to CTLME

= *129,880 tons of P*/85,500,000

=0.0015 tons of P/a/capita or *1.5 kg of P/a/capita*

Although the Philippines has the highest P load as a whole to the CTLME and drastic measures and intervention need be done to curb pollution, it has a lower per capita P load to the CTLME than Malaysia.

Per capita P contribution of Malaysia* **to CTLME**

=*13,820 tons of P*/3,000,000

=0.0046 tons of P/a/capita or *4.6 kg of P/a/capita*

*Contribution of Malaysia to the CTLME is based only on the state of Sabah.

Although Malaysia as a whole has the smallest P load to the Coral Triangle, per capita it has the biggest contribution, partly due to the fact that a lot of industrial crop exports such as oil palm are grown in Sabah. Oil palm uses the most fertilizers which leach into the soil

Per capita P contribution of Indonesia** **to CTLME**

=*45,810 tons of P*/(220,000,000x0.17)

=0.0012 tons of P/a/capita or *1.2 kg of P/a/capita*

**Contribution of Indonesia is 17% of its total population; East Indonesia's total population.

Indonesia has the lowest per capita P load to the CTLME among the three countries albeit its total P load is bigger than Malaysia's

The CTLME then has a yearly stock of 189.51 kt of P or 189,510 tons of P coming from the above ASEAN countries.

It is also interesting to note the difference between N and P in the flow *uncertain food*. The ratio of *uncertain food* to the food value coming from *Agriculture* and *Aquaculture* is much higher in the case of N than P. This may be because of the reason that Asians normally eat a diet lower in protein than the Europeans.

In a paper written by Vaclav Smil, he mentions that although the "understanding of human N (protein)" has gone through a lot of study, it is quite certain that populations from richer countries have a far bigger consumption of protein than hundreds of millions of people in Asia, Africa and Latin America. Smil also opines that these "disparities" may be bridged by better practices in agriculture and "higher feeding efficiencies" resulting to enough nutrition without bigger increases in N inputs (Smil, 2002).

Lastly, it is very important to note that N flows into the country stocks are significantly higher than the flows to the CTLME. This is an environmental problem because even though reaction time is slow, these stocks will be future emissions into the CTLME. Although nutrient inflows in the future would have been reduced or even eliminated, the situation that these nutrients are already in stock creates a huge dilemma.

V-Summary, Recommendations, and Conclusion

A-Philippines

Nitrogen

Table 1. Most Significant N Flows, Philippines

Source	Flow	Amount (kt)	Destination
To Nourish	*N hhwaste, lf*	342.1	*Landfill*
Agriculture	*N to soil*	193	*Soil*
Aquaculture	*N aqwaste, r*	183.8	*Rivers*
Landfill	*Nlandfill, r*	170.6	*Rivers*
Rivers	*N river, m*	339.4	*Marine Area*

One of the most important flows in the *Philippines Country Sub-system* comes from *To Nourish*. The N from food industry waste, as well as kitchen waste, and human sewage dumped in landfills totaled 342,100 tons. The Philippines has not been spending on secured landfills. At the same time legislation forbids incineration. Nevertheless, controlling leaching of N from biodegradable waste can be managed by treating leachate from landfills. Treatment can be done by introducing microorganisms to the leachate. The microorganisms will process the said nutrient and achieve a product that can be introduced back to waterways without much contamination. The Philippines has not spent much on waste management. Unlike utilities such as electricity, one of the highest rates in the region, management of waste is not a shared burden of the populace.

Another important flow is the flow of N from commercial fertilizers in *Agriculture*. The outflow is estimated at 193,000 tons/annum, of which 145,000 tons stay in the *Soil*. In this study the *Industrial Agricultural Soil* is differentiated from the bigger *Soil* sub-sytem in the environment. It is recommended that agricultural practices should be reviewed to minimize the load of N from fertilizers to the soil. Furthermore, the flow *N excretions* amounting to 507,500 tons/annum can be utilized so that N in commercial fertilizers will be minimized. If utilized properly it will also lessen the flow of *N manure, rivers* as well as the uncontrolled leaching of N to *Soil*.

Table 2. Summary of N in Soils, Philippines

	Sub-system	Sum, Inflows (kt)	Stock (kt)	Sum, Outflows (kt)
Industrial Agricultural Soil	*Agriculture*	552.4	270.4	282
Soil	*Country*	193	145	48

From the soil, an estimated 48,000 tons run off to rivers. The biggest flow to *Marine Area* come from *Rivers* totaling 339,400 tons/annum. The biggest input flow to *Rivers* come from *Aquaculture* totaling 183,800 tons/annum. The second biggest come from Landfills which amounts to 170,600 tons/annum. It is ideal that any liquid wastes discharged into rivers should be controlled or treated. The presence of fishponds in the Philippines, gives the chance for aquaculture practitioners to explore a natural treatment using trickle ponds and biological treatment for their liquid wastes. This also goes with treating leachate from landfills. Biodegradable waste can also be composted to produce agricultural fertilizers. Treating aquaculture waste waster and landfill leachate alone can reduce the load of the Philippines by 355.4 kilo tons or 335,400 tons of N/annum, comprising over 100% of the N load of the Philippines to the CTLME.

Phosphorus

One of the most significant P flows come from *Agriculture*. *P to soil* amounted to 54.90 kt or 54,900 tons. The source of this P flow comes from *P fertilizers com* or commercial fertilizers. Like N in fertilizers, the utilization of P in *Agriculture* should be properly reviewed to achieve more efficiency.

Table 3. Summary of P in Soils, Philippines

	Sub-system	Sum, Inflows (kt)	Stock (kt)	Sum, Outflows (kt)
Industrial Agricultural Soil	*Agriculture*	281.6	159.3	122.3
Soil	*Country*	54.9	41.2	13.7

Furthermore it is also important to note that one of the biggest inflows of P in *Agriculture* is *P other food*. This accounts for the P not found in other commercial feeds as well as feeds from fishmeal. They may have come from fishmeal from sea catch. There is also a possibility that imported and commercial feeds are more enriched with P than what the researcher estimated.

Like in the N SFA, *Rivers* contribute most to the P load in *Marine Area*. The biggest inflow to *Rivers* is run-off from *Soil* which is estimated with a 25% transfer coefficient. *P Manure, r* or the flow of P from manure to rivers is also a significant flow amounting to 10,630 tons or 10.63 kilo tons/annum. Since P is a substance that is mined, it is therefore important that they are utilized efficiently and kept in their proper sinks such as *Industrial Agricultural Soil* at an optimized level so that they do not leach into the environment. It is therefore essential to have an efficiently timed and proper dosage for the application of P fertilizers. It is also recommended to utilize *P excretions* and convert them into fertilizers.

Lastly, *P sewage, r* or the P load to rivers from sewage contributes 10,880 tons or 10.88 kilo tons/annum to Rivers. An important intervention with be waste water treatment plants which treat the P before the wastewater is discharged into the rivers.

Table 4. Most Significant P Flows, Philippines

Source	Flow	Amount (kt)	Destination
Agriculture	*P to Soil*	54.9	*Soil*
	P other food	168.3	*Animal Breeding*
Soil	*P run-off, r*	13.7	*Rivers*
Agriculture	*P manure,r*	10.63	*Rivers*
To Nourish	*P sewage, r*	10.88	*Rivers*
Rivers	*P river, m*	28.7	*Marine Area*

B. Malaysia

Nitrogen

Malaysia's biggest flow come from commercial fertilizers. As mentioned in the section on *Agriculture* for Malaysia, a problem of leaching occurs in peat soils. The second biggest flow is N to soil which becomes an inflow to the greater *Soil* of the environment.

Table 5. Summary of N in Soils, Malaysia

	Sub-system	Sum, Inflows (kt)	Stock (kt)	Sum, Outflows (kt)
Industrial Agricultural Soil	*Agriculture*	101.76	30.52	71.24
Soil	*Country*	71.21	39.21	32

Therefore, the FAO study encouraged inter-cropping to maximize the fertilizer use (FAO, 2004). The researcher also believes that these peat forests should be conserved instead. It is always a tough decision to choose between forest conservation and developing agro-industry in an impoverished area.

Another significant flow is N run-off from Soil to Rivers estimated to be 32 kt or 32,000 tons of N/annum. Lastly, N from Rivers to Marine area is estimated at 35.4 kt, 90% of the total 39.17kt N contribution of Malaysia to the CTLME

Table 6. Most Significant N Flows, Malaysia

Source	Flow	Amount (kt)	Destination
	N fertilizers com	104.8	*Soil*
Agriculture	*N to soil*	71.21	*Soil*
Soil	*N run off, r*	32	*Rivers*
Rivers	*N river, m*	35.4	*Marine Area*

Phosphorus

Like with the N SFA, the most significant flow is *P fertilizers, com* amounting to 47.7 kt of P/annum. Of this amount leaching into *Industrial Agricultural Soil*, more than 99% comes from fertilizer residues. The scenario shows that because of the problem of leaching in peat soils converted to palm oil plantations, there should be a solution in optimizing fertilizer use such as intercropping suggested in the FAO Fertilizer Study (FAO, 2004). Furthermore, another significant flow is P flow from *Agriculture* leached into the greater *Soil* amounting to 33.27 kt/annum.

Table 7. Summary of P in Soils, Malaysia

	Sub-system	Sum, Inflows (kt)	Stock (kt)	Sum, Outflows (kt)
Industrial Agricultural Soil	*Agriculture*	47.54	14.27	33.27
Soil	*Country*	33.27	18.27	15

Of the above value, an estimated 45% of P is leached into *Rivers* as run-off. *Soil* run-off contributes to the most of the P leached into *Rivers*. *Rivers* then contribute a value of 13kt or 13,000 tons of P/annum to *Marine Area*. *Marine Area* has a total load to the CTLME of 13.82 or 13,820 kt of P/annum.

Table 8. Most Significant P Flows, Malaysia

Source	Flow	Amount (kt)	Destination
	P fertilizers com	47.7	*Agriculture*
Agriculture	*P to soil*	33.27	*Soil*
Soil	*P run-off, r*	15	*Rivers*
Rivers	*P river, m*	28.7	*Marine Area*

Because Malaysia as a country has started on using waste water treatment plants as an intervention to improve water quality, it helps reduce the P load from sewage into the CTLME. It also is a fact that part of Malaysia within the CTLME has a relatively smaller population that the Philippines and East Indonesia.

C. Indonesia

Nitrogen

Table 9. Most Significant N Flows, Indonesia

Source	Flow	Amount (kt)	Destination
	N, fertilizers com	575	*Industrial Plant Cultivation*
	N other food	*324.15*	*Animal Breeding*
Agriculture	*N to soil*	188.4	*Soil*
Landfill	*Nlandfill, r*	74.6	*Rivers*
To Nourish	*N sewage,r*	49.24	*Rivers*
Rivers	*N river, m*	128.2	*Marine Area*

It is important to note that the biggest source of N in Indonesia is from commercial fertilizers. Indonesia relies heavily on agriculture both for its populace and for export so that is understandable. Nevertheless, it is recommended that efficiency in agriculture should further be attained. Again, it is optimum to use organic fertilizers from plant residues and biomass as well as excretions from Indonesia's animal industry.

Table 10. Summary of N in Soils, Indonesia

	Sub-system	Sum, Inflows (kt)	Stock (kt)	Sum, Outflows (kt)
Industrial Agricultural Soil	*Agriculture*	503.7	282.7	221
Soil	*Country*	188.4	141.3	47.1

Of the outflows from Industrial Agricultural Soil an estimated 188.4 tons of N/annum enters the greater *Soil* sub-system. Of this N load, 47.1 kilo tons leach out to *Rivers*. However, the biggest load to *Rivers* come from *Landfills* totaling 74.6 kilo tons of N. The next biggest flow comes from sewage. *N sewage, r* totalled 49.24 kilo tons. Treating landfill leachate as well as continuing the development of waste water treatment plants in all parts of the country will help reduce the N load to the CTLME.

It is also interesting to note that one of the biggest flows come from *N other food* that go into *Animal Breeding*. This may come from trash fish from fisheries (sea caught) converted to feeds. It is also a possibility that there are more feed imports not included in the computations of this study. It would be optimal to convert food scraps from food industry and commerce to animal feeds, so as to lessen the load of N on landfills as well as save resources on animal feeds.

Phosphorus

The biggest flow of P in the Indonesia SFA comes from commercial fertilizers. It is estimated that out of 175 kt of P/annum 159.7 kt reach the soil as residue. A further 106.3 kt is contributed by animal excretions estimating 153.2 kt of P to remain in *Industrial Agricultural Soil* while 102 kt leave are leached into the greater *Soil* of the environment.

Table 11. Summary of P in Soils, Indonesia

	Sub-system	Sum, Inflows (kt)	Stock (kt)	Sum, Outflows (kt)
Industrial Agricultural Soil	*Agriculture*	266	153.22	112.78
Soil	*Country*	102	75.8	26.2

P in *Rivers* contribute the most to the load of Marine Area with 37.3 kt or 37,300 tons/a, as much as 83% of the 45.81 kt of P in *Marine Area* that go into the CTLME. It is also interesting to note, that of all the P flows into *Rivers*, run-off from soil contribute the most with 26.2 kt of P/annum. Indeed the prudent use of P fertilizers and the utilization of animal excretions as a source of P can reduce this P load into *Soil* and *Rivers*. Another significant flow to Rivers is P from animal manure disposed in waterways estimated at 10.63 kt/annum. Lastly, 10.88 kt of P come from sewage disposed in *Rivers*. The increase in wastewater treatment plants will indeed help reduce P load to *Rivers*.

Table 12. Most Significant P Flows, Indonesia

Source	Flow	Amount (kt)	Destination
	P, fertilizers com	175	*Industrial Plant Cultivation*
	P other food	*131.65*	*Animal Breeding*
Agriculture	*P to soil*	102	*Soil*
Agriculture	*P manure, r*	10.63	*Rivers*
To Nourish	*P sewage,r*	10.88	*Rivers*
Rivers	*N river, m*	128.2	*Marine Area*

Lastly there is a great amount of P other food. Like in the N system, this consists of animal feed not accounted for in the computations of the study. This may include trash fish from sea catch as well as a greater import of animal feed.

The various countries have different scenarios on their sources and pathways for N and P. Nevertheless, the bottom line is that one day without controlling N and P in the Coral Triangle, its water quality, marine life and the people who are directly relying on this large marine ecosystem will be greatly affected. It has also been proven that interventions are needed to prevent pollution. Wastewater treatment plants, landfills properly treating leachate and the prudent use of commercial fertilizers are viable solutions.

It is also important that lessons learned from each country should be disseminated to the other countries straddling this very special ecosystem. The example of Malaysia that has long since advocated the use of wastewater treatment plants is a testament to this. This brings forth another aspect of cooperation between the countries specially those within ASEAN. Like other regions in the world, it is ideal for the Coral Triangle Countries to achieve a legally binding and enforceable solution to pollution. This study can be one of the initial bases for this undertaking. The Coral Triangle Initiative (CTI-CFF) can one day evolve into such a legally binding agreement. Then local scientists would need to verify the results of this study. Someday it would be up to them and the local populace to change the results of this study for the better. It is the only instance when this researcher would like to be proven wrong.

VI- A Glossary of Conversion Values

A. Crude Protein and N Percentage in Crops

Ccp: Crude protein percentage in crops used as feeds; 42%; See page 29 for computations.
Cip: Crude protein percentage from imported crop materials; Pegged at the same value as *Ccp*.
Npp: Percentage of N in protein; 16%; See page 29 for reference; Source: Craig and Helfrich.
Ppcp:Average percentage of crude protein in a basket of Philippine crops; 4%; See page 20-21..
Ppc1: Average percentage of crude protein in crops group 1; 12%; See pp. 20-21 for computations.
Ppc2: Average percentage of crude protein in crops 2; 3.2%; See page 20-21 for computations.
Ppc3: Same as *Ppc2*.

B. Crude Protein Percentage of Fishmeal and Prepared Fish feeds and N Percentage of Fish

Cfp: Crude protein percentage from prepared fish feeds; 40%; See page 30.
Clf (Philippines and Indonesia): Crude protein percentage in local fishmeal used in this study for Philippines and Indonesia; 33%; Source: Nur; See page 32 for computations.
Clf (Malaysia): Crude protein percentage in local fishmeal used in this study for Malaysia; 70% Source; See pp 61.
Cmp(Philippines and Indonesia): Crude protein percentage from imported fish meal material used in this study for the Philippines and Indonesia; 72.5%; See page 30 for computations.
Npf:N percentage in fish; 3%; See page 31.

C. N in Excretion and Waste

Nep: N excretion in kg per chicken per year; 52kg; Source: Anderl et. al., for Umweltbundesamt Austria; See page 24.
Neh: N excretion in kg per pig per year; 10.3 kg; Source: Anderl et. al., for Umweltbundesamt Austria; See page 24.
Ner: N excretion in kg per ruminant per year; 53.6kg; Source: Anderl et. al., for Umweltbundesamt Austria; See page 24.
MaN: Percentage of N in a particular animal manure used in the aquaculture industry; In this study chicken manure was used in MaN; 3.9%; Source: Mitchel et. al.; See page 26.
Enf: Percentage of N excretion for every ton of fish; 5.1%; Source: Lazzari and Baldiseratto; See page 33.
Nks: Per capita N from kitchen waste that goes to sewage; 200g/a; Source: Baccini and Brunner; See page 35.
Nkg; Per capita N from kitchen waste that goes to garbage; 300g/a; Source: Baccini and Brunner; See page 35.
UrN; Amount of N a human urinates per annum; 2,600g/a; Source: Baccini and Brunner; See page 36.
FcN=amount of Na human excretes (solid wastes) per annum; 490g/annum; Source: Baccini and Brunner; See page 36.

D. P Percentage in Crops, Feed Crops
Pcr; P percentage in crops; 0.06%; Source Tacon; See page 39-49.
Pfc: Average percentage of P in feed crops; 0.40%; Source Tacon; See page 40.

E. P Percentage of Fishmeal, Prepared Fish feeds, Fish
Pff: P percentage in fish; 0.4 %; Source: Hayse-Gregson; See page 45.
Pmp; P percentage from imported fish meal material; 2.27%, Source: Tacon; See page 46.
Ppf: P percentage from prepared feeds(prawn feeds x share of prawn farming in the aquaculture market); 0.027% See pp 44-45.
Ppp=P percentage prepared feeds;1.02%; Source: Tacon; See page 44.

F. P Excretion in Waste

MaP; P_2O_5 percentage in Manure; 3.7%; Source: Mitchel et. al.; See page 43.
Epf: Percentage of P excretion for every ton of fish; 0.87%; Source: Lazzari and Baldorotto; See page 47.
Pks: Per capita P from kitchen waste that goes to sewage; 20 g/annum; Source: Baccini and Brunner; See page 48.
Pkg: Per capita P from kitchen waste that goes to garbage; 40 g/annum; Source: Baccini and Brunner; See page 48.
UrP: Amount of P a human urinates per annum; 270 g per annum; Source: Baccini and Brunner; See page 48.
FcP: Amount of P a human excretes (solid wastes) per annum; 100 g/annum. Brunner and Baccini; See page 48.

VII-Bibliography

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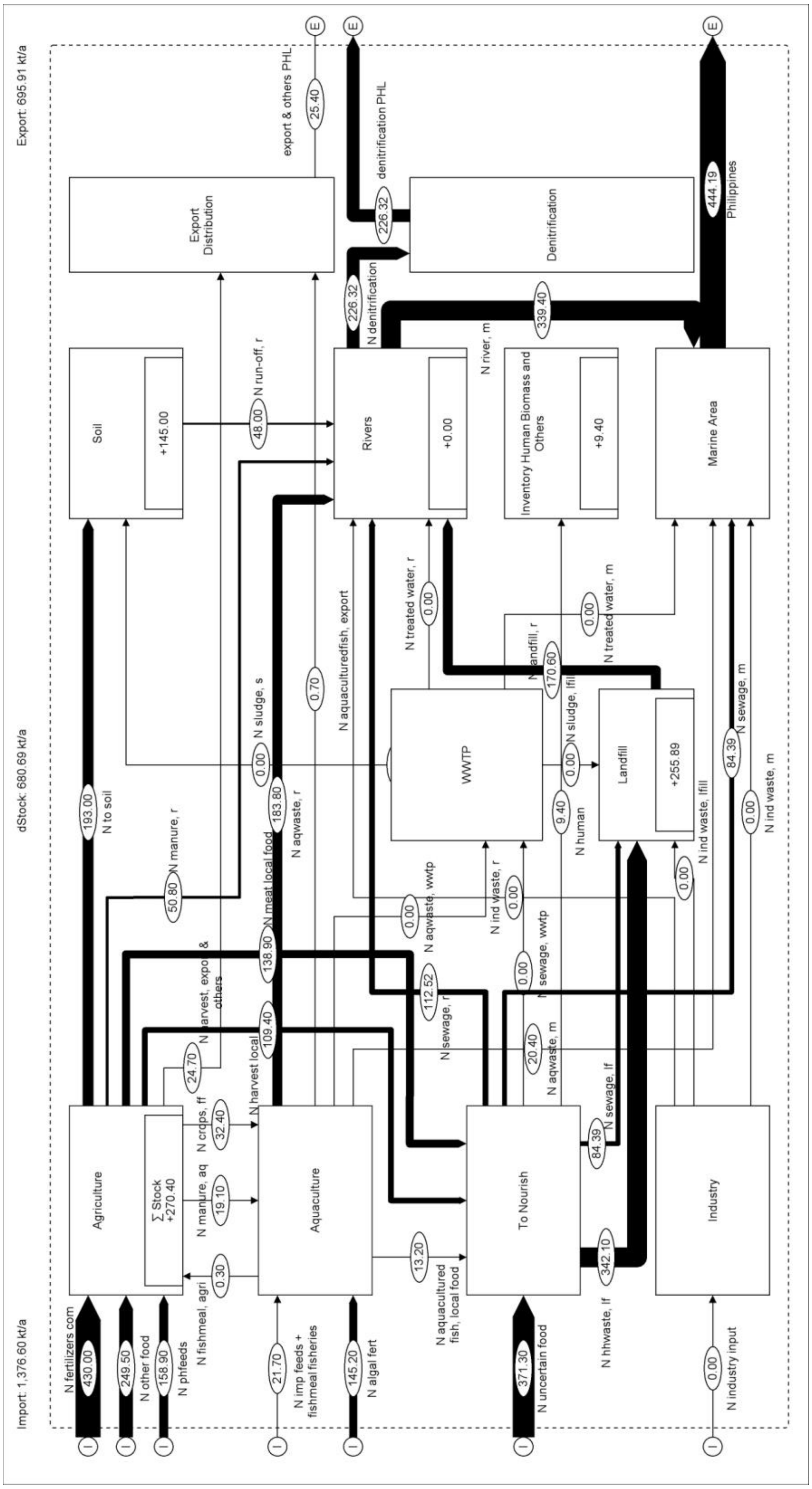
VIII-Annex

Annex 1. N Country SFA, Philippines (kt/a)



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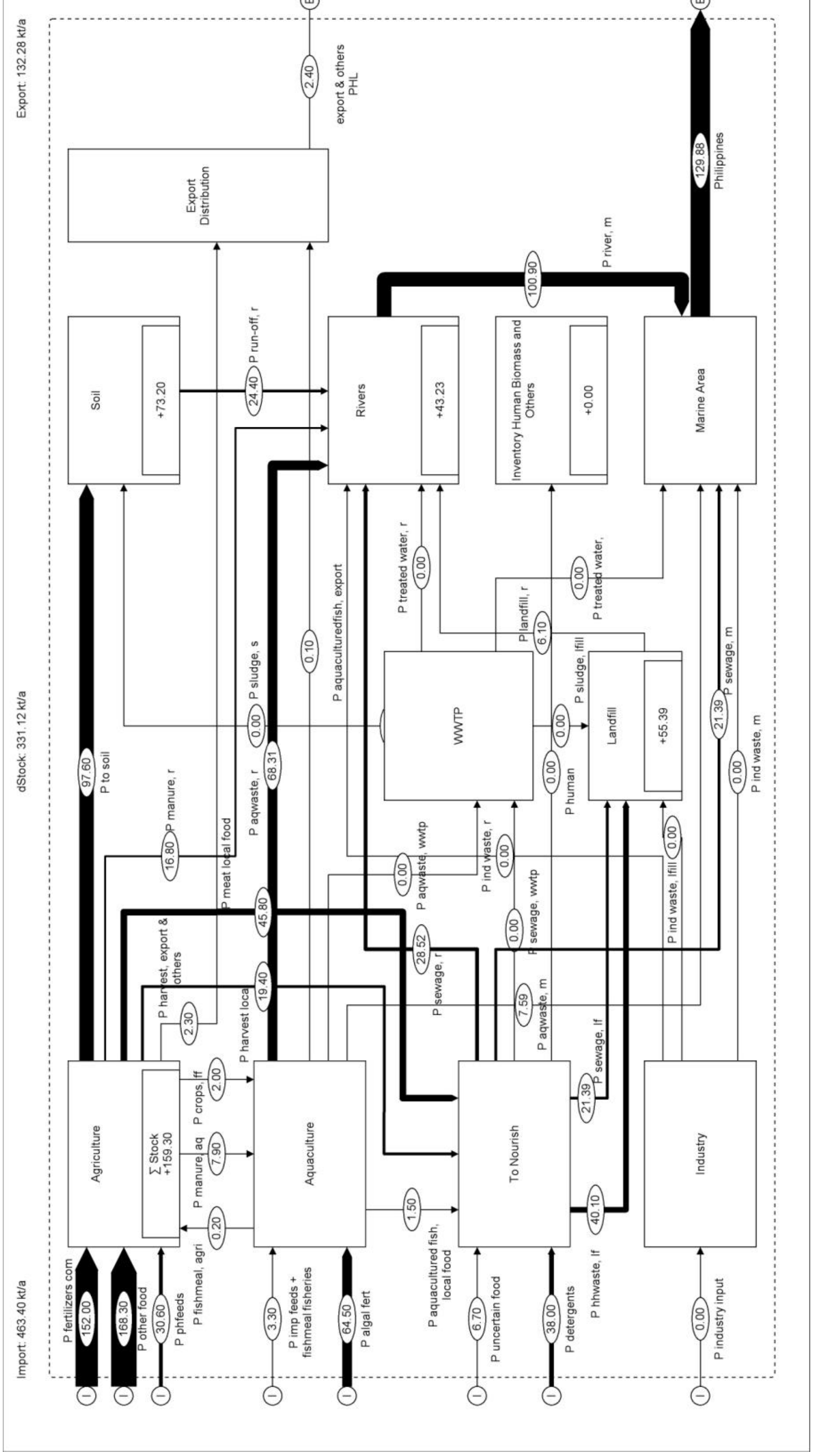

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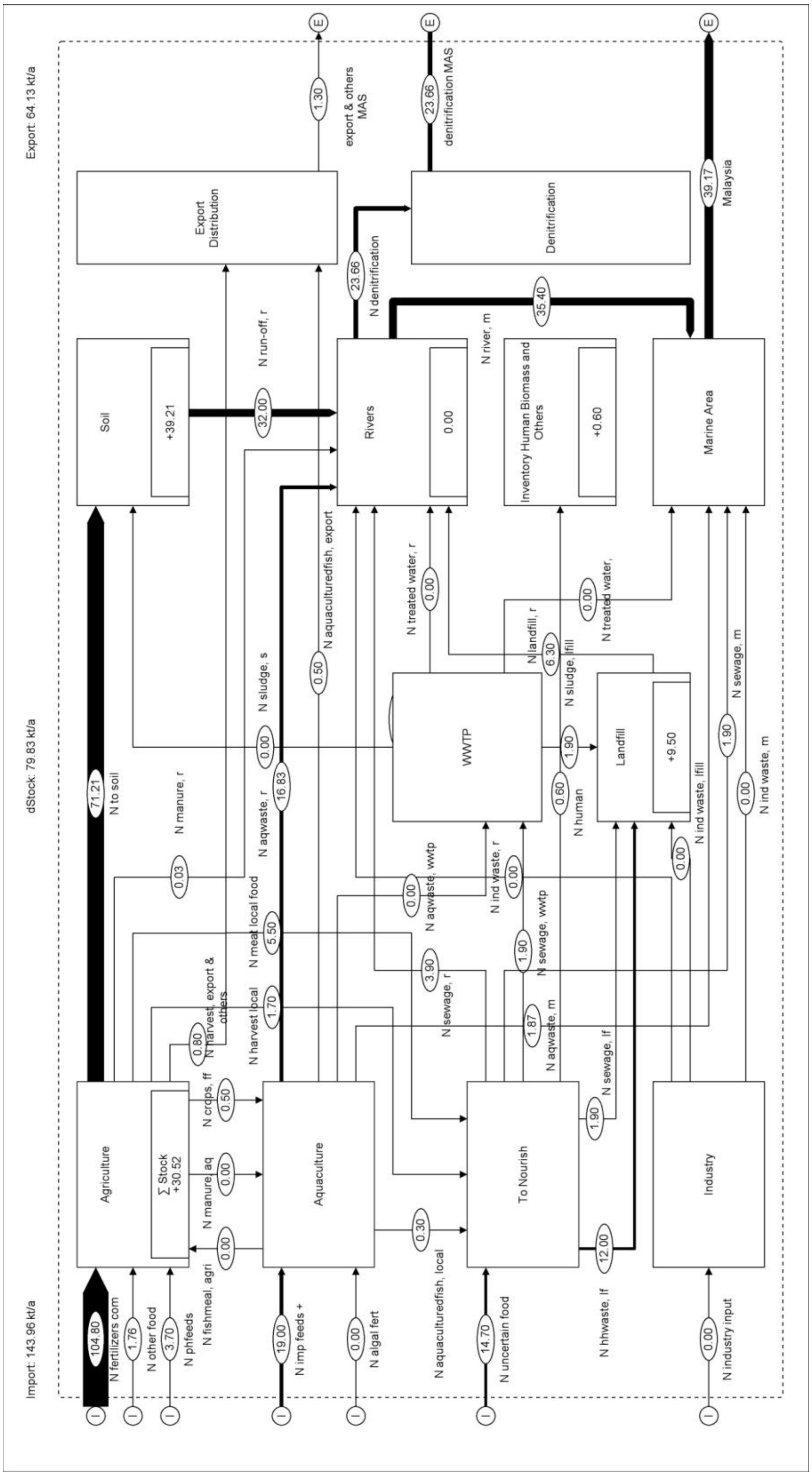

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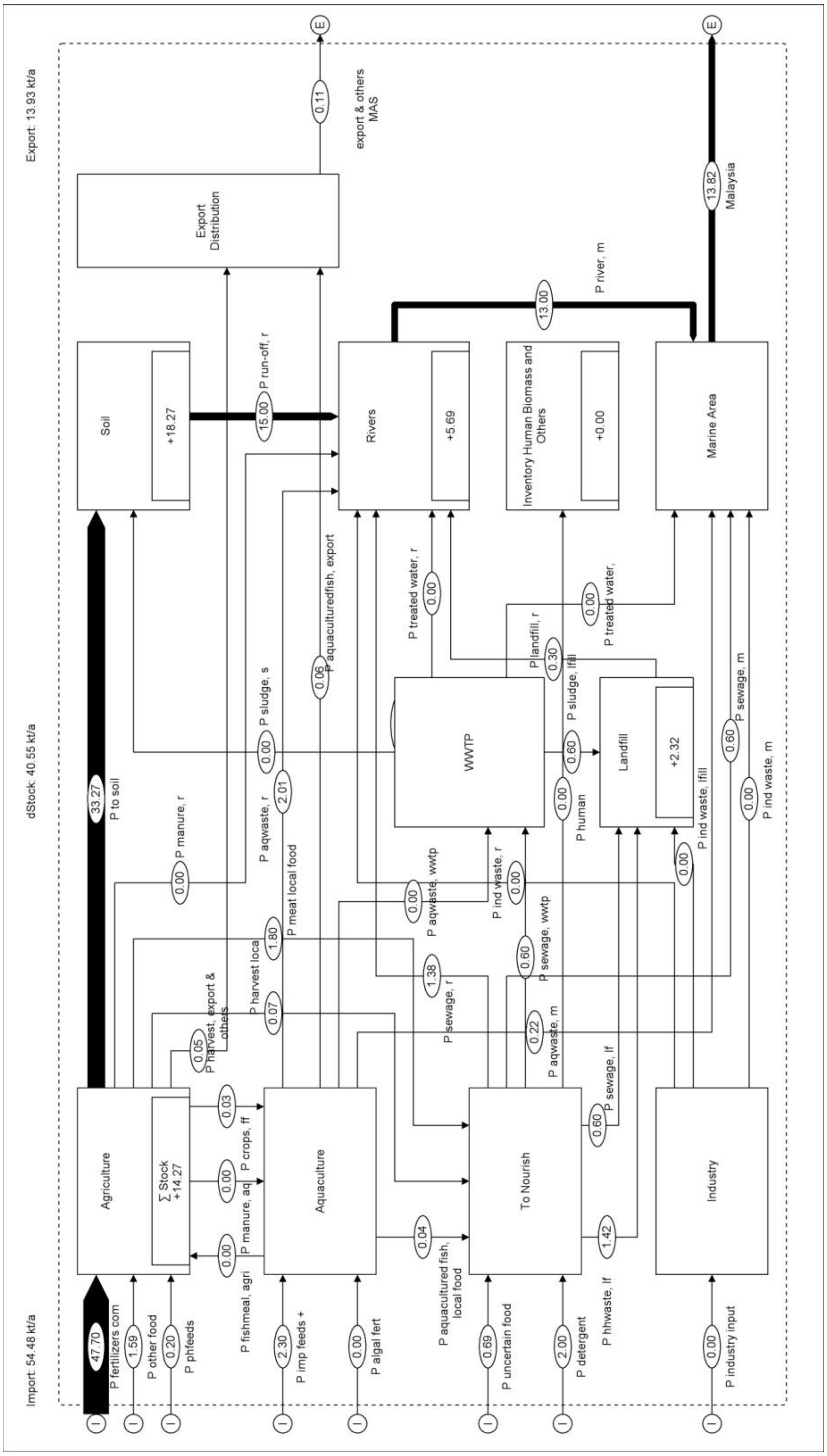
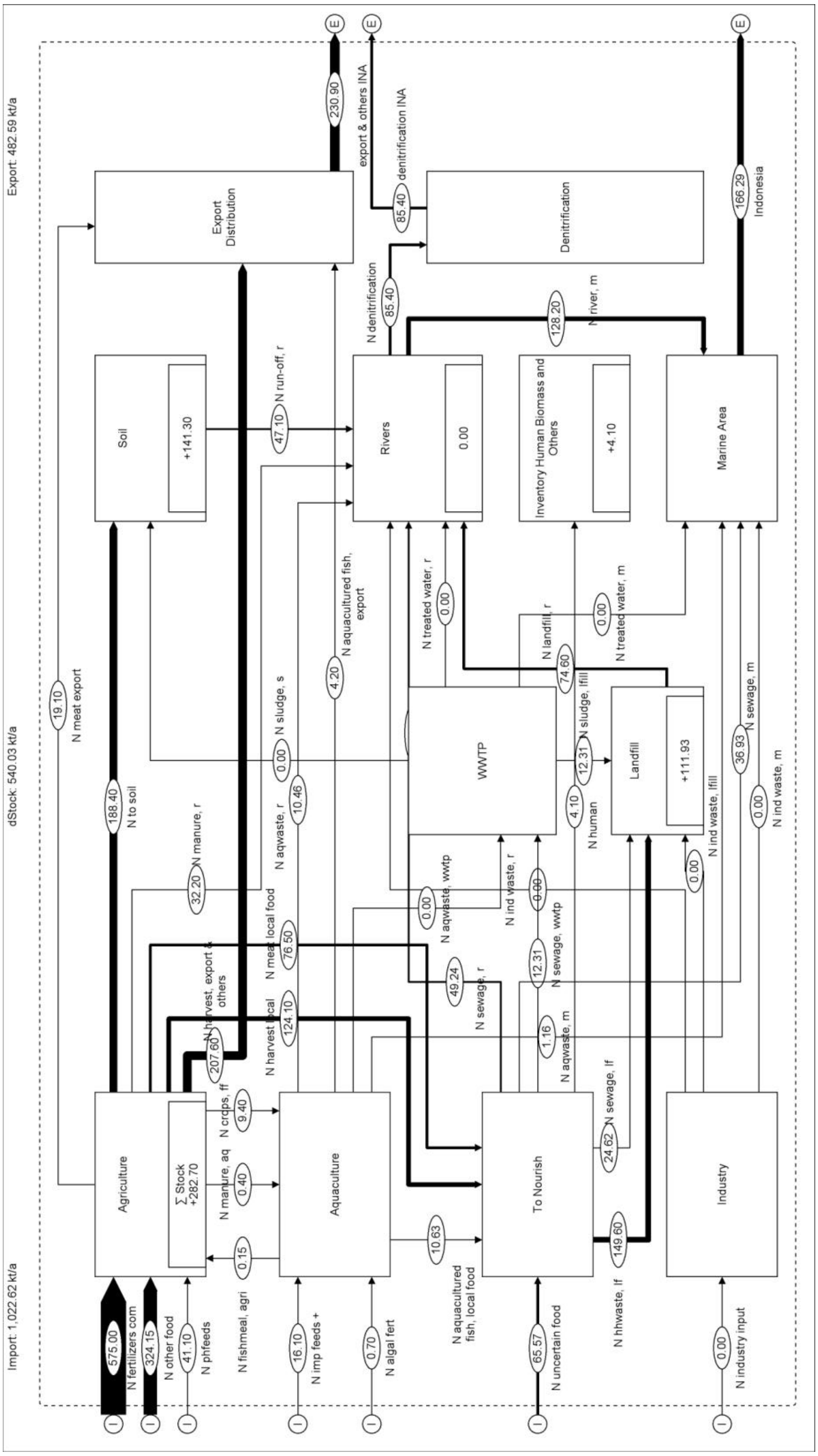


Annex 5. N Country SFA, Indonesia (kt/a)



Annex 6. P Country SFA, Indonesia (kt/a)