Review on the Population Growth Impacts to Environment–The Case of the Philippines

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ABSTRACT

Population growth elsewhere had inflicted the environment through resource extraction and pollution load. However, few literatures dealt on associating the influence brought by population to environment in developing countries. This became the interest of the present review highlighting the case of the Philippines. Key issues evaluated in the present review were anchored from the national research agenda in environmental science with modifications to fit the study objectives, namely: (i) population; (ii) environment; and (iii) mitigation. Qualitative and quantitative analyses were employed to analyze secondary data drawn from government agencies and 71 indexed journals (Clarivate Analytics-Web of Science and Elsevier-Scopus). Overall, the Philippines increasing population compromised environmental quality ranging from fuel demand, forest cover loss, air emissions, water pollution, and public health. The demand to sustain growing population need for food and economic opportunities exacerbate these environmental ill effects. However, mitigating measures can be expedited through sound science education, affluence, and technology. Institutions may cascade these proactive environmental policies by giving opportunities to urban peripheries through decentralization of resources and shifting towards alternative energy. These measures may provide environment-economic dividends given the large population age group of working class in the country. Present review is preliminary and provides a baseline on the population to environment linkage in the Philippines.

Keywords: population growth, environmental impacts, environmental quality, mitigation, and Philippines

Contents

1. INTRODUCTION

Global population growth became limelight debate from the Malthusians and Cornucopians perspective (Desrochers and Hoffbauer, 2009) and uncertainties in its projections (Sotto, 1983; Lutz *et al*., 1997; Lutz *et al*., 2001; Cohen 2003). Also, the issue of carrying capacity and tragedy of the commons owing to population growth (Hardin, 1991; Cohen, 1995) provided biological insight to previous socioeconomic population perspective. Relative to this, it has always been the case of developed nations to draw a global consensus of population impacts to environment, necessitating regional-local study to present the case particularly among developing nations.

The population growth rate of the Philippines declined (1.6%) with disproportionate density despite being demographically young among Southeast Asian countries. For example the proportion of young population 0-14 years declined from 46.0% in 1970 to 33.4% in 2010 (Abrigo *et al*., 2016). This was accounted to decrease in fertility over the last half of the century owing to birth control regulations, technology, and education (Lutz *et al*., 1997; Lutz *et al*., 2001; Potts, 2007; Abrigo *et al*., 2016). Nonetheless, the shifting demographics may present both opportunities and threats to the Philippines carrying capacity context to support growing population.

Growing population among the working age group in the Philippines presents soci-economic opportunities. Age group of 15-64 years old increased from 51% in 1970 to 62.3% in 2010 (Abrigo *et al*., 2016), boosting the economic mobility and productivity of future workers. This resulted to high GNI (gross national income) per capita of 1801.6 USD on 2010. Uniquely, the GNI tripled with fertility rate declining by half since 1960 (Abrigo *et al*., 2016) (see **Table 1**).

Table 1. Trends in income and fertility in the Philippines, 1960-2010 (Abrigo *et al*., 2016)

Parameters	1960	1970	1980	1990	2000	2010
GNI per capita (2010 USD)	644.0	756.3	1049.3	952.7	1193.8	1801.6
Total fertility rate	6.5	5.9	5.0	4.1	3.5	3.0
By area of residence						
Urban	-	4.4	4.0	3.5	3.0	2.6
Rural	-	6.7	5.7	4.8	4.3	3.5

Likewise, the narrowing gap between urban and rural population from 1960-2010 (Abrigo et al., 2016; see Table 1) presents the decentralization trend in the Philippines calling for exurbanite system, wherein urban workers opted to reside in rural areas (O'Toole, 2009). This case is expected among developing nations to prosper, giving economic opportunities to businesses and manufacturing facilities in urban peripheries. Moving to rural areas to avoid high taxes, regulation, and congestion provides cost effective gains (Nelson *et al*., 1995 as cited by O'Toole, 2009).

On the contrary, this economic benefit from present population density has drawbacks due to unlikely environmental pressure. Demand for goods and services will likely go up burdening the environment mainly to improve living standards among growing population groups (Pimentel *et al*., 1999; Southgate, 2009; Pimentel *et al*., 2010) despite the affordability of resources on the historical perspective (Goklany, 2009). For example, the Philippines material inputs grew by 2.4% yearly which is about 293 million tons in 1980 to 661 million in tons in 2014.This also entails a total domestic processed output released to the environment of 260 million tons in 2014 from 96 million tons in 1980, resulting to 89% as air emission (Martinico-Perez *et al*., 2018). Consequently, the issues of environmental sustainability indicators of resource utilization like energy and landuse shift and environmental degradation through pollution generation emerged as inflicted by population (Cuffaro, 1997; Pimentel *et al*., 1999; Harte, 2007; Pimentel *et al*., 2010). These issues are studied in the Philippines however the causal influenced of population to environment is unexplored. This necessitates the present review on estimating population impacts to the environment. Elucidating the environmental ill effects of population growth is important to extrapolate sound science of the local implication of population to environment, representative of the conditions in the developing countries.

This preliminary review paper aimed at synthesizing the environmental impacts of population growth in the Philippines. Estimates were drawn from assessing the energy resource demand, landuse shift, agricultural productivity, and pollution generation as a function of growing population. Proposed mitigating typology through education, science & technology, institution & policy, and socioeconomic factors are similarly presented anchored from the proposed national research agenda in environmental science.

2. MATERIALS AND METHODS

2.1. Method framework

This paper tries to present a preliminary review of the environmental impacts brought by population and draw inspiration to mitigate environmental problem in the Philippines. The study framework (see **Fig.1**) was anchored from the national agenda on environmental science with modifications to fit the study objectives (Hunter, 2000; Gloklany, 2009). The framework presents the inter-linkage of Philippines population to environmental goods and services and in return inflicts environmental burden as output (Pimentel *et al*., 1976, Pimentel *et al*., 1999; Pimentel and Pimentel, 2003; Harte, 2007; Potts, 2007; Pimentel *et al*., 2010).

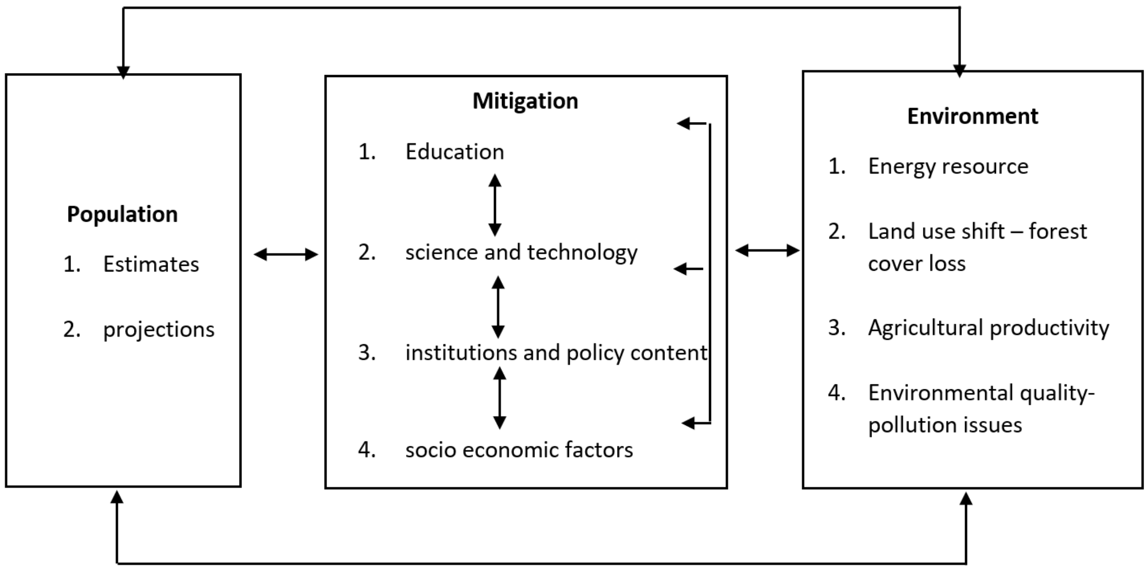

Figure 1. Method framework anchored from the national research agenda in environmental science

Environmental goods and services withdrawn and inflicted by increasing population included: (i) energy resource; (ii) land use shift-forest cover loss; (iii) agricultural productivity; and (iv) environmental quality-pollution issues; all were considered key issues in the Philippines environment. Likewise, mitigating options were highlighted drawing inspiration from literature as practiced elsewhere (Bjorkland and Pringle, 2001; Hudson, 2001; Aguilar *et al*., 2008; Goklany, 2009; O'Toole, 2009; Southgate, 2009; Pimentel *et al*., 2010; Abrigo *et al*., 2016; Agbola *et al*., 2017; Fujii, 2017). These mitigating factors promote proactive conservation efforts, poverty alleviation, and population reduction. Overall, the framework illustrates the overarching influence populations puts to the environment and how population may present mitigating factors to create sustainable environment.

2.2 Data gathering procedures

All data assessed in the present review were secondary. Population projection and estimate (medium assumption) data were drawn from the Philippine Statistics Authority (PSA). Environmental quality data were culled from PSA, Department of Environment and Natural Resources (DENR) bureaus (EMB and NSWC), Department of Energy (DOE), and 71 publications (80% of the total references) verified and indexed by Clarivate Analytics-

Web of Science and Elsevier-Scopus. The Clarivate Analytics-Web of Science (WoS) mainly comprised of science citation indexed (SCI), science citation index expanded (SCIE), social science citation index (SSCI), emerging sources citation index (ESCI), and zoological record. These journal indexing were given premium as measure of paper publication quality used as reference in the present review. Few however were peer -reviewed papers with emphasis on local environmental quality studies (see **Fig.2**).

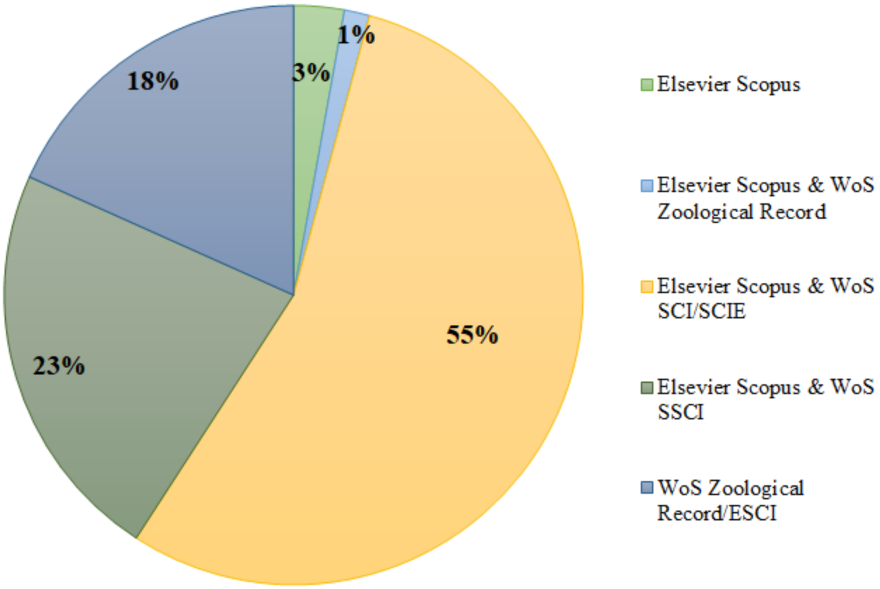

Figure 2. Indexing of journal publications used as reference in this review

2.3 Data analysis

The paper review is descriptive-comparative employing both qualitative and quantitative analyses. All data were assessed inferentially. Pearson correlation was employed to associate population projection at medium assumption to environmental quality parameters (agricultural productivity, air quality emissions, and land based pollution). Further, regression was also used to find the line best fit and coefficient of determination associating parameters drawn from Pearson correlation. Likewise, One-way ANOVA was employed to identify difference among air pollutant parameters per anthropogenic source within the years evaluated. All data were processed at α – 95% ($p < 0.05$).

3. RESULTS AND DISCUSSION

3.1 Energy resource

The population increase over the century (**Fig.3**) greatly shaped the use and process flow of natural resources specifically energy. Since 1850 the world population growth accounts for 52% of the energy growth, while growth in per capita energy used was responsible for 48% (excluding causal connections between population and energy use per capita) (Hodlren, 1991). This data presents the influence of population growth to energy demand. The increase in energy consumption can be an indirect measure of how population inflicts the Earth's life-support systems (Holdren & Ehrlich 1974, as cited in Daily *et al.*, 1994). Consequently, energy can be scarce and costly as population grows resulting to material deprivation and economic struggles.

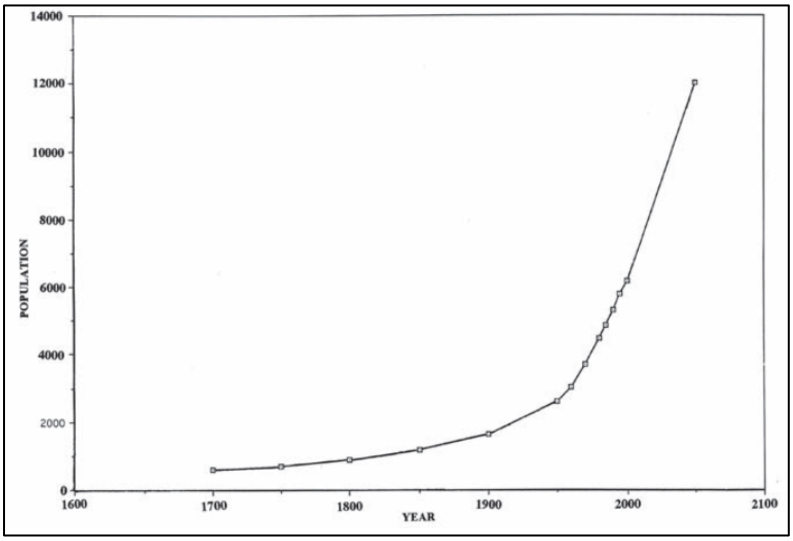

Figure 3. World population growth and projected growth based on the current population growth rate of 1.3% per year (Pimentel and Pimentel, 2003)

3.1.1 Regional-sectorial energy demand

Developing countries like the Philippines are faced with sociopolitical issues with energy use owing to capping of carbon dioxide emission and limited resource. This is despite the very low energy consumption (30%) true for all developing nations than developed nations with 70% fossil fuel energy use (Pimentel *et al.*, 1999; Pimentel *et al.*, 2010). Nonetheless, a strong causality between energy prices and economic growth can be identified in the case of the Philippines (Asafu-Adjaye, 2000) as evidence of population growth.

The impact of population growth to energy use is reflected in the Philippines energy sales and consumption for 2015-2016. This reflects the increase within two years, which can be associated to increasing population. Data presents disproportionate percentage per regional islands. Luzon for example had the highest energy sales and consumption for commercial, whereas Mindanao for industrial and residential. Urbanized metropolis like NCR in Luzon is mainly populated by commercial sectors accounting to greater energy sale/consumption.

On the other hand, specific data on energy use in the Philippines per household for 2004-2011 showed increased in energy use and type as population increased. Evaluated matrices were the: (i) type of fuel used; (ii) fuel for lighting; (iii) fuel for cooking; (iv) fuel heating water; and (v) vehicle. Particularly, household means of cooking increased for electricity use (see **Fig.4**). The same increase was also noted for boiling water, although a trend likewise shifted towards the use of fuel wood, charcoal, and biomass residues. Consequently, alternative energy resources are consumed at the household level owing to high cost of nonrenewable energy. Likewise, the use of gasoline to run vehicles increased from 2004-2011 indicative of economic growth driven by population.

3.1.2 Correlation analysis on energy demand

We can also present an association between the Philippines population and energy consumption in the succeeding text. To elaborate, **Fig.5** presents the population projection at medium assumption vs. power consumption (GWh), and power generation (e.g. coal and natural gas (GWh)) on 2003 to 2010. It can be extrapolated that power consumption covering all sectors (e.g. residential, commercial, industrial, and others) increased as population increases within the studied period (r – 0.955; p – 0.0002; r^2 – 0.91265). Comparable trend was also noted for power generation by coal (p – 0.0125; r^2 – 0.67329) and natural gas (p – 0.0015; r^2 – 0.8332). The coefficient of determinations (r^2) and Pearson correlation (r) can be a proxy to represent the linearity although not a causal relationship between population projection and power consumption and power generation (coal and natural gas) was established. Power generation data accounts to electricity supply in the country supplementary to other renewable energy sources (e.g. geothermal, hydropower, solar, and wind). Overall, this depicts how population in the Philippines may influence energy demand, consumptions, and sales particularly on nonrenewable energy source.

Data shows the dependency of the Philippines on fossil fuel with 44.7% of its source being imported as per DOE 2016 Total Primary Energy Supply report corroborating graphed data in **Fig.5**. The growing need of nonrenewable energy similarly degrades the environment as population increase (Pimentel *et al*., 1999; Pimentel *et al*., 2010). With the environmental pressure it is more sustainable to shift towards renewable energy resource to convey environmental protection (Dincer, 2000; Panwar *et al*., 2011) while stimulating the economy as population grows.

TABLE 2B Types of Fuel Used by Households for Cooking, Philippines: 2004 and 2011

Type of Fuel	Percentage of Households that Used Specific Type of Fuel for Cooking	
	2011	2004
Total Number of Households (In thousands)	20,969	16,973
Electricity	17.5	13.8
LPG	40.5	52.0
Kerosene	2.1	8.6
Fuelwood	54.0	54.9
Charcoal	35.3	30.2
Biomass residues	20.1	16.1
Biogas	*	-

Notes: A household may report more than one type of fuel used.
Excludes households whose electricity source is other than utilities and distribution companies.
For 2004 HECS, the reference period is from October 2003 to September 2004 (that is, 12 months prior to survey).
For 2011 HECS, the reference period is from March to August 2011 (that is, 6 months prior to survey).
* Less than 0.1 percent.

Source: National Statistics Office and Department of Energy
2004 and 2011 Household Energy Consumption Survey (HECS)

TABLE 2C Types of Fuel Used by Households for Heating Water, Philippines: 2004 and 2011

Type of Fuel	Percentage of Households that Used Specific Type of Fuel for Heating Water	
	2011	2004
Total Number of Households (In thousands)	20,969	16,973
Electricity	3.8	2.0
LPG	2.0	6.4
Kerosene	0.1	1.4
Fuelwood	20.1	5.8
Charcoal	11.2	2.3
Biomass residues	6.2	0.9
Biogas	*	-

Notes: A household may report more than one type of fuel used.
Excludes households whose electricity source is other than utilities and distribution companies.
For 2004 HECS, the reference period is from October 2003 to September 2004 (that is, 12 months prior to survey).
For 2011 HECS, the reference period is from March to August 2011 (that is, 6 months prior to survey).
* Less than 0.1 percent.

Source: National Statistics Office and Department of Energy
2004 and 2011 Household Energy Consumption Survey (HECS)

TABLE 2D Types of Fuel Used by Households for their Vehicle, Philippines: 2004 and 2011

Type of Fuel	Percentage of Households that Used Specific Type of Fuel for Their Vehicle	
	2011	2004
Number of Households that Used Any Vehicle During the Reference Period (In thousands)	5,465	2,370
Gasoline	88.4	82.3
Diesel	15.6	21.0
Auto LPG	0.1	-
Others	0.4	1.6

Notes: A household may report more than one type of fuel used.
Vehicles used by households refer to those owned by the household, owned by their office/company or rented.
Other types of fuel used by households for their vehicles include alcogas and cocodiesel.
For 2004 HECS, the reference period is from October 2003 to September 2004 (that is, 12 months prior to survey).
For 2011 HECS, the reference period is from March to August 2011 (that is, 6 months prior to survey).

Source: National Statistics Office and Department of Energy
2004 and 2011 Household Energy Consumption Survey (HECS)

Figure 4. Philippines household energy type and use for 2004-2011(raw data source: doe.gov.ph)

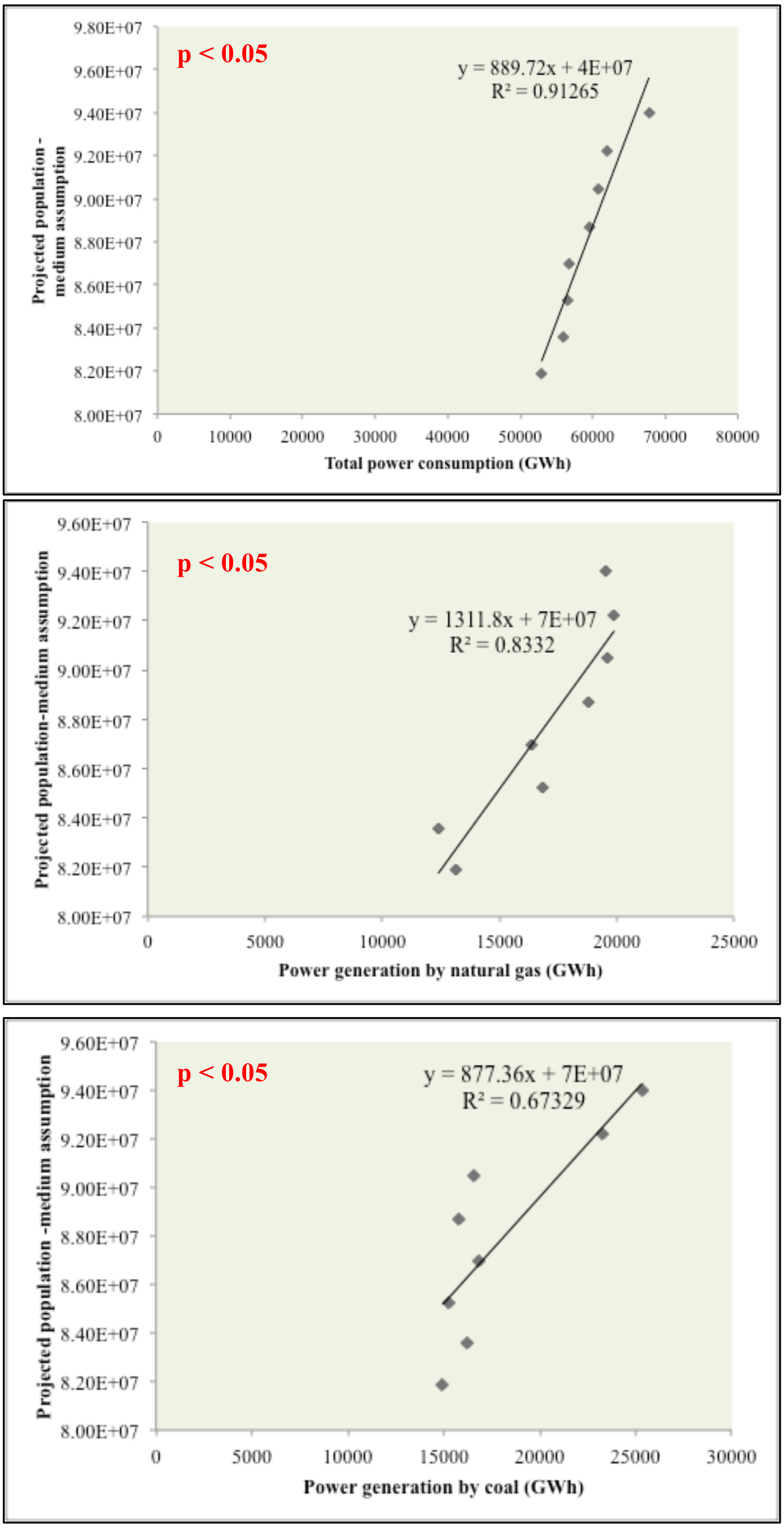

Figure 5. Philippines power consumption (GWh) vs. projected population-medium assumption for 2003-2010 (raw data sources: doe.gov.ph; psa.gov.ph)

3.2 Landuse shift- forest cover loss

The increase in population resulted to changing landscape of the planet as the need to grow food and identify areas for human settlement increases. Consequently, the issues of the commons and carrying capacity (Hardin, 1991; Cohen, 1995) often coined to elucidate the impact of population to changing environment emerged. Globally there is a consensus on the measurable projection on the shortages of fertile land (Pimentel *et al*., 2010). This can be attributed to the need of more cropland while reducing forest-woodland and pasture-grassland (Liu *et al*., 1993; Goklany, 2009) as population increases (see **Fig.6a**). Likewise, population increase resulting to urban sprawl can best describe the land resource loss (Hase and Lathrop, 2003). Changing landuse has inherent ill effects like wildlife and habitat loss (see **Fig.6b**) and reduction in forest-woodland (Harte, 2007). This overarching issue of population to landuse and agriculture necessitates reviewing the Philippines case as a vulnerable island nation to climate change.

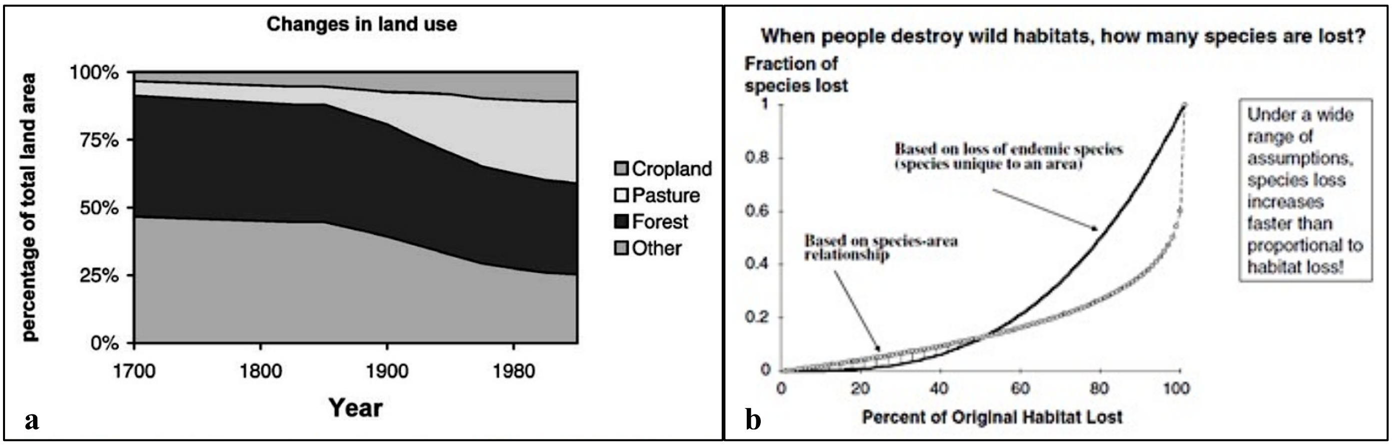

Figure 6. a) Estimated changes in land use from 1700 to 1995 (Goldewijk and Battjes, 1997, as cited in Lambin *et al*., 2001) and b) non-linear relationship between land degradation and species extinction (Harte, 2007)

3.2.1 Terrestrial forest cover loss

The Philippines landuse greatly shifted like forest cover loss (1934-2010) as population increased (1903-2015) (see **Fig.7**). From **Fig.7** we can see an association of how population may influence the environment in search of resources from the land. Philippines was once forested by 80%-90% and reduced to <20%, deforestation being the problem (Bankoff, 2007; Suarez and Sajise, 2010). By 1934 forest cover was reduced to 57% but conservation efforts reduced it to sparingly 23% land area (Licuanan *et al*., 2019). At large changing landuse compromised protected areas (Verburg et al., 2006), loss of carbon sink (Lasco and Pulhin, 2000), and ecological disturbance to animals' natural habitat (Posa and Sodhi, 2006) in the country. All effected systems owing to forest loss are supposedly vital to increase resiliency to climate change. Another threat was brought by mining and quarrying in search of mineral deposits and excavation of land to reclaim urban areas.

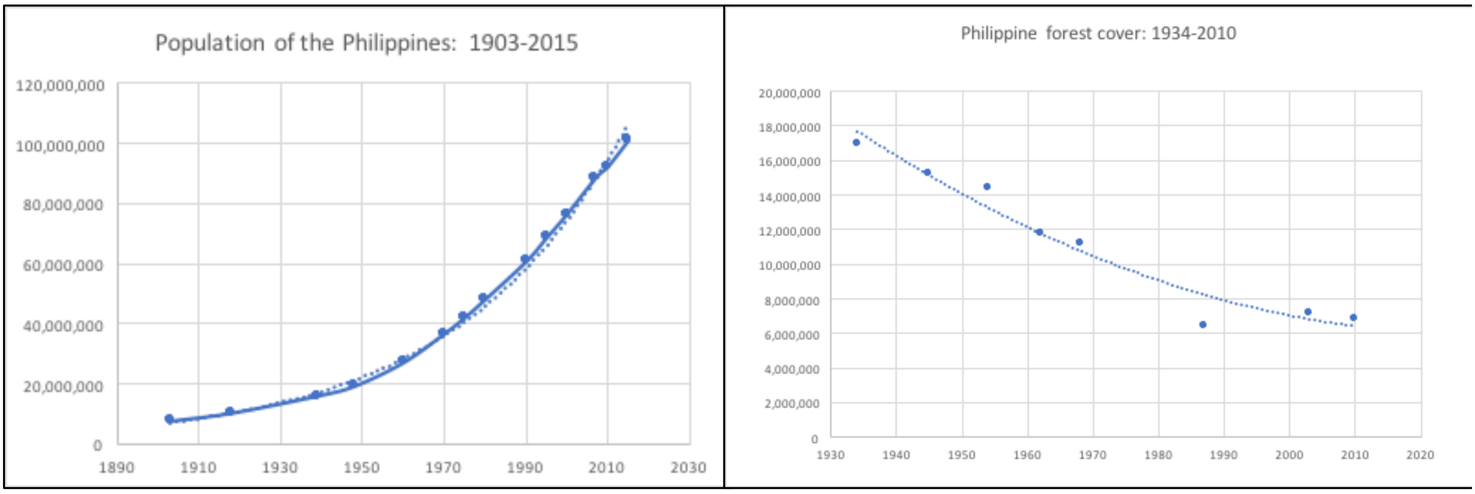

Figure 7. Population (1903-2015) and forest cover (1934-2010) trend in the Philippines

We may consider the study of Verburg and Veldkamp (2004) elucidating how forest cover loss in the country influenced land use. **Fig.8** presents the simulation data of the Philippines forest cover in two scenarios. Scenario 1 shows a spatial spread of deforestation in the country. Further deforestation with 'hot zones' is compromised in Sierra Madre mountain range, Palawan, Samar, and Mindanao. Scenario 2 presents the land use change due to logging restrictions. Agricultural production particularly overlaps logging area, causing forest cover to decrease in Northern Mindanao (Verburg and Veldkamp, 2004). This data presents how forest cover changes over time corroborating data presented in **Fig.6-7**. Overall, the change in forest cover of the country can be linked to increasing population.

3.2.2 Mangrove forest cover loss

Mangrove forest is one of the underrated tropical ecosystems when discussing about forest cover loss. In the Philippines about 4500 km^2 of mangrove cover were estimated in 1920 dropping to 1325 km^2 in 1990 (Primavera, 1995; Valiela *et al*., 2001). Current literature in the country suggests threats owing to population growth related activity like aquaculture development. Between 1968 and 1983, 237,000 ha of mangroves were lost for pond construction (Garcia *et al*., 2014). Similarly, urbanization has led to reduction of mangrove forest like the case of Banacon Island and Bais Bay where mangrove timbers were sold as firewood to bakeries and industries in Cebu (Walters, 2003). Overall, this section highlights how population growth in the country may influence landuse in terms of forest cover (e.g. terrestrial forest and mangrove forest).

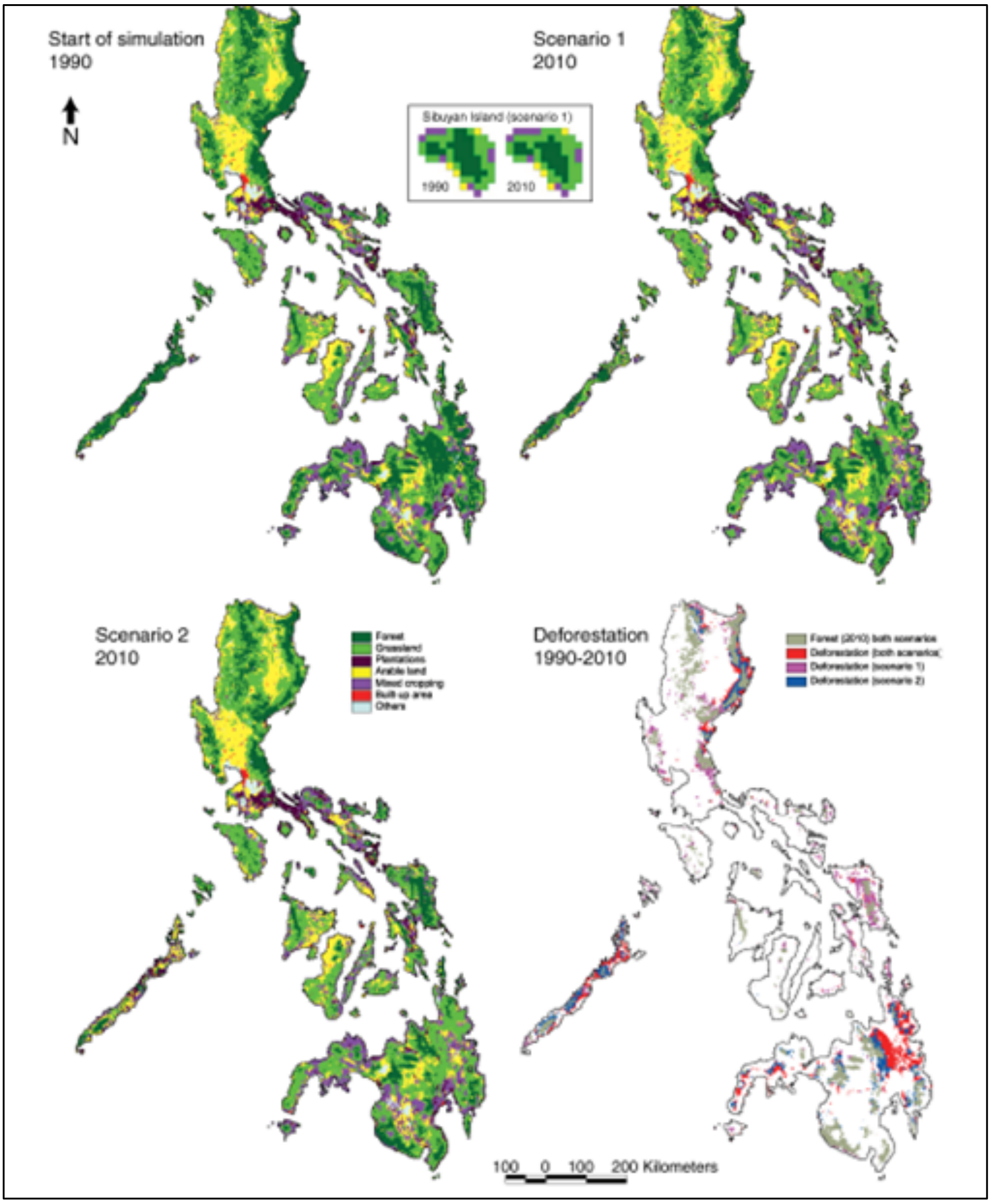

Figure 8. Land use in the Philippines in 1990, results of the simulation of two scenarios for 2010 and areas deforested between 1990-2010 (Verburg and veldkamp, 2004)

3.3 Agricultural productivity

The increase in population puts pressure to the land and best measured in terms of agriculture productivity as proxy to population-economic linkage. This is particularly important among developing nations securing food productivities, land-labor productivities, and land property rights (Cuffaro, 1997). As population increase the need to shift land use for agriculture increased resulting to land degradation (Pimentel *et al*., 1976; Matson *et al*., 1997; Foley *et al*., 2005; Southgate, 2009). For example, changing land use practices resulted to 2 billion tons increase per year of world grain harvest owing to 'green revolution' but jeopardized the land with soil erosion and pesticide residues (Foley *et al*., 2005). Overall, this requires economic-conservation efforts and institutional arrangements to mitigate the problem while supporting the food need of growing population.

3.3.1 Crop productivity

The Philippines agricultural productivity showed remarkable increase in crop, livestock, and poultry yields from 2013 to 2017 (see **Table.2-3**) to support growing population. This results to shifting landuse like forest loss to increase agricultural productivity in the case of Northern Mindanao, Philippines (Verburg and Veldkamp, 2004). This also corroborates the paper of Briones (2005) where land use shift can be attributed to agricultural intensification. In contrast, fishery production showed reduction in volume ('000mt) from 2013-2017 (see **Table.4**) as evidence of common resource depletion (Jodha, 1985).

Table 2. Philippine crops volume of production (2013-2017) in '000 mt

Crop	2013	2014	2015	2016	2017
Palay	18,439.4	18,967.8	18,149.8	17,627.2	19,276.3
Corn	7,377.3	7,770.6	7,518.8	7,218.2	7,914.9
Coconut	15,354.3	14.696.3	14,735.2	13,825.1	14,049.1
Sugarcane	24,584.8	25,029.9	22,926.4	22,370.5	29,286.9
Banana	8,646.4	8,884.9	9,083.9	8,903.7	9,166.3
Pineapple	2,458.5	2,507.1	2,582.7	2,612.5	2,617.7
Coffee	78.6	75.5	72.3	68.8	62.1
Mango	816.4	885.0	902.7	814.1	737.0
Tobacco	53.8	61.4	56.2	56.5	51.0
Abaca	65.0	68.1	70.4	71.8	68.8
Peanut	29.1	29.2	29.2	27.9	29.4
Mongo	32.4	32.1	33.6	34.0	35.3
Cassava	2,361.6	2,540.3	2,714.3	2,755.1	2,806.7
Sweet potato	528.2	519.9	536.0	529.5	537.3
Tomato	207.7	214.6	214.8	210.7	218.8
Garlic	9.0	9.0	10.4	7.5	7.8
Onion	134.2	203.7	181.2	122.6	184.4
Cabbage	127.5	128.0	125.8	123.1	122.5
Eggplant	219.9	225.6	232.9	235.6	241.9
Calamansi	164.1	160.7	162.7	118.2	116.7
Rubber	444.8	453.1	398.1	362.6	407.0
Others	3,606.4	3,545.3	3,587.1	3,535.9	3,560.5
Total	**85,739.4**	**87,007.9**	**84,324.6**	**81,631.9**	**91,552.5**

Source: psa.gov.ph

Table 3. Philippines livestock and poultry volume of production (2013-2017) in '000mt

Type	2013	2014	2015	2016	2017
Livestock (liveweight)	2,507.0	2,532.5	2,627.1	2,745.4	2,775.8
Poultry (liveweight)	1,589.5	1,606.4	1,694.4	1,706.7	1,777.0
Egg	468.8	457.2	487.0	505.6	537.8
Total	**4,565.3**	**4,596.1**	**4,808.5**	**4,958.7**	**5,090.6**

Source: psa.gov.ph

Table 4. Philippines fisheries volume of production (2013-2017) in '000mt

Type	2013	2014	2015	2016	2017
Commercial	1,067.6	1,107.2	1,084.6	1,016.9	948.3
Municipal	1,264.4	1,244,3	1,216.5	1,137.9	1,126.0
Aquaculture	2,373.4	2,337.6	2,348.2	2,200.9	2,237.8
Total	**4,705.4**	**4,689.1**	**4,649.3**	**4,355.8**	**4,312.1**

Source: psa.gov.ph

The overall trend in land use to support grain production also increased particularly for irrigated palay, rainfed palay, palay, and yellow corn (see **Fig.7**). These are staple crops as carbohydrate source among Filipinos. The increase in production (**Table.2**) and land use as proxy by land area harvested (**Fig.7**) showed the need to support food requirement among increasing population. We can similarly associate projected population-medium assumption to area harvested for these valued crops for 2003-2010 (see **Fig.7**). Overall, a strong correlation with significant difference, and selective linear relationship can be drawn between population projection to total area harvested for irrigated palay (r- 0.946; p – 0.0004 ; r^2 – 0.8946), palay (r -0.885; p -0.0034; r^2 – 0.7841), and yellow corn (r- 0.874; p – 0.00457; r^2 – 0.7633). This hypothetically presents how population may influence crop land use in the country.

3.3.2 Energy and landuse shift for crop production

Likewise, there is evidence of energy use increase to intensify agriculture, with electric consumption per capita being significantly related to agriculture real gross value added (Urrutia *et al*., 2018). We can use energy data of the Philippines particularly on power generation on coal and natural gas (GWh) versus area harvested for crops (irrigated palay, rainfed palay, palay, and yellow corn) on the same period (2003-2010). Pearson correlation analysis showed association between power generations by natural gas to area harvested for irrigated palay (r – 0.889; p – 1.0282×10^{-5}; r^2- 0.7909), palay (r – 0.832; p – 0.0104; r^2 – 0.6922), and yellow corn (r – 0.874; p – 0.0045; r^2- 0.7637) (see Fig 9). The data may not best represent for the energy use via natural gas (feedstock to manufacturing of fertilizer and pesticide) in the agricultural sector, however, may present a hypothetical association to total area of crop harvested.

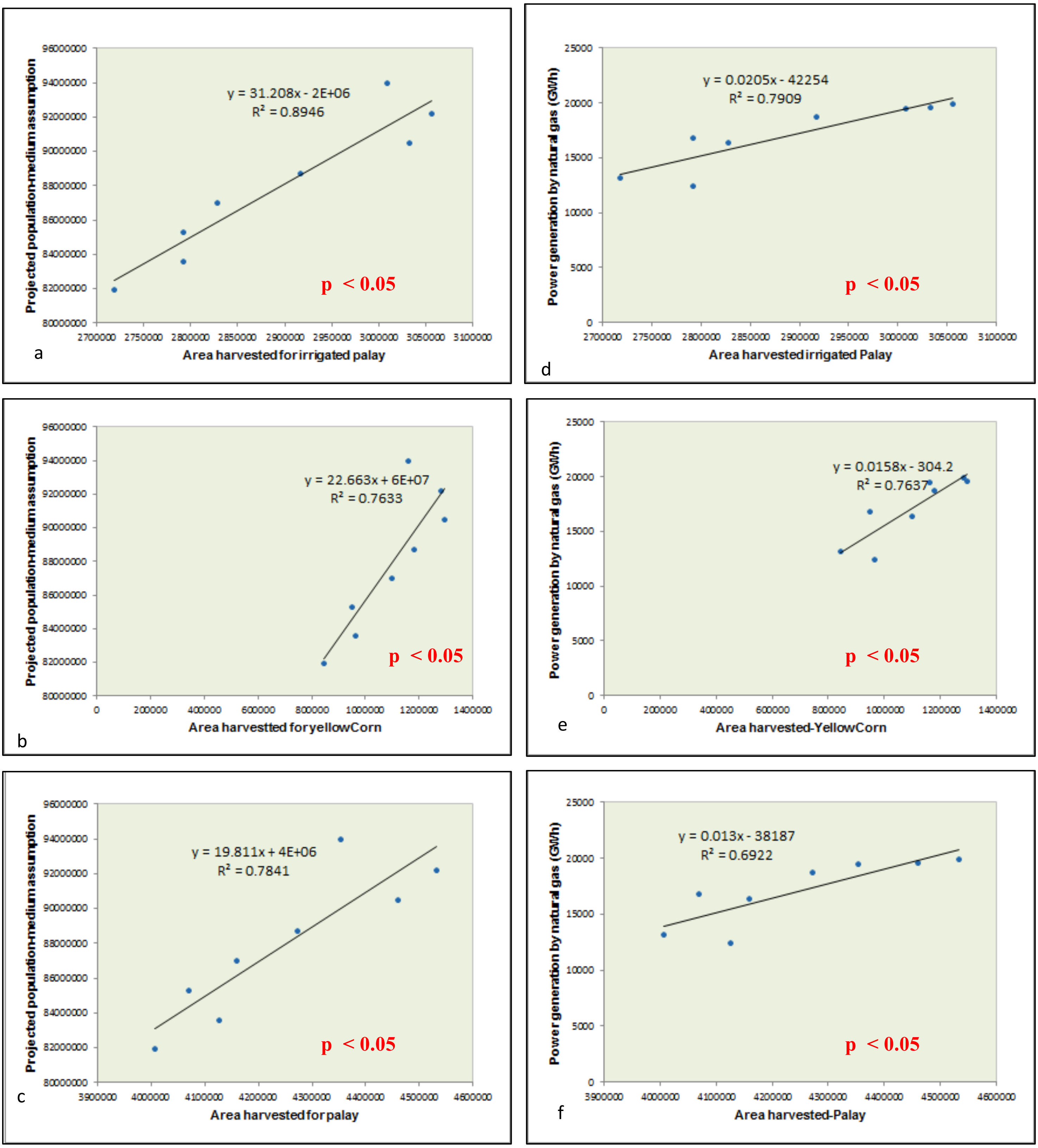

Figure 9. Significantly correlated matrices α–95% ($p<0.05$) of agricultural productivity to population and energy: (i) Projected population-medium assumption vs. total harvested area (2003-2010): a) irrigated palay; b) yellow corn; c) palay; and (ii) Power generation (natural gas) vs. total harvested area for 2003-2010 d) irrigated palay; e) yellow corn; f) palay (raw data sources: doe.gov.ph; psa.gov.ph)

3.3.3 Livestock and energy dependence

Unlike fisheries, livestock production increased rapidly (**Table.3-4**) in the Philippines owing to institutional mediation to support growing population (Jodha, 1985). Livestock productivity increased (see **Table.5**) with significant correlation to population projection-medium assumption for year 2003-2010 (r – 0.994; p < 0.05). This supports previous discussion of growing population needing more food resource. Likewise, a significant correlation was found between livestock and increasing power generation on coal (r -0.852; p < 0.05) and natural gas (r- 0.882; p < 0.05) (see **Table.5**). Present global average meat consumption is 100 g per person per day, with about a ten-fold variation between high-consuming and low-consuming populations (McMichael *et al*., 2007). Consequently, this consumption pattern owing to growing population requires big energy expenditure to grow more livestock and increase commodity production being an environmental burden (Huijbregts *et al*., 2010). This reflects an environmental feedback loop of population growth influencing energy and agriculture demands (Harte, 2007). Overall, this section presents the increasing energy demand and landuse shift needed for agricultural productivity to support growing population (Pimentel *et al*., 1999; Pimentel *et al*., 2010).

Table 5. Significant correlation matrices between livestock to power generation by natural gas & coal, and population (raw data sources: doe.gov.ph; psa.gov.ph)

Variables	Projected population-medium assumption	Livestock volume production	Power generation by coal (GWh)	Power generation by natural gas (GWh)
Projected population-medium assumption	1			
Livestock volume production	0.994*	1		
Power generation by coal (GWh)	0.815*	0.852*	1	
Power generation by natural gas (GWh)	0.913*	0.882*	0.585	1

*Pearson correlation; significant α – 95% (p < 0.05)

3.4 Environmental quality-pollution issues

The insatiable need of growing population have altered the biophysicochemical nature of the planet. Issues of air, water, and land pollution became a synergistic feedback of the environmental burden brought by population growth and varied density (Cole & Neumayer, 2004; Eriksson & Zehaie, 2005; Harte, 2007). The discussion that population may be the culprit to pollution problems in the Philippines is viewed unlikely. Contemporary research in the country dealt on commercial, industrial, transportation, institutional, and governmental sectors as pollution sources. This way of scientific conditioning requires paradigm shift to fully understand that a growing population is the main problem why pollution issues exist.

3.4.1 Air pollution

Pollution issue in the country is peculiarly important being a developing nation with greater population density and urbanization growth rate. These were found to be significantly proportional to atmospheric carbon dioxide emissions reflective of the implications for the environmental Kuznets curve (Cole and Neumayer, 2004). Air quality monitoring had been conducted in the Philippines, although most literature focused in the National Capital Region and other cities in Luzon dealing on the presence of polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides, and black carbon emissions (Santiago & Cayetano, 2007; Santiago & Cayetano, 2011; Alas *et al.*, 2018). All analyses were indicative of urban air pollution as economic activity-anthropogenic input of population. Likewise, the air total suspended particulate (TSP) analysis in NCR showed high levels although a decline in concentration was observed from 2007-2016 (see **Fig.10a**). This can be attributed to institutional remedies and strong academe based research addressing air quality issues.

Other cities in the Philippines showed rapid urbanization trend due to population increase. Consequently, the need to abate air pollution related issues must be preempted to provide emission regulation. This is necessary as the present data on total vehicle acquisition nationwide increased from 2004-2014 (**Fig.10b**). If poorly managed adding to polluting inherent nature, vehicles comprised the bulk of mobile air pollutants in the metropolis.

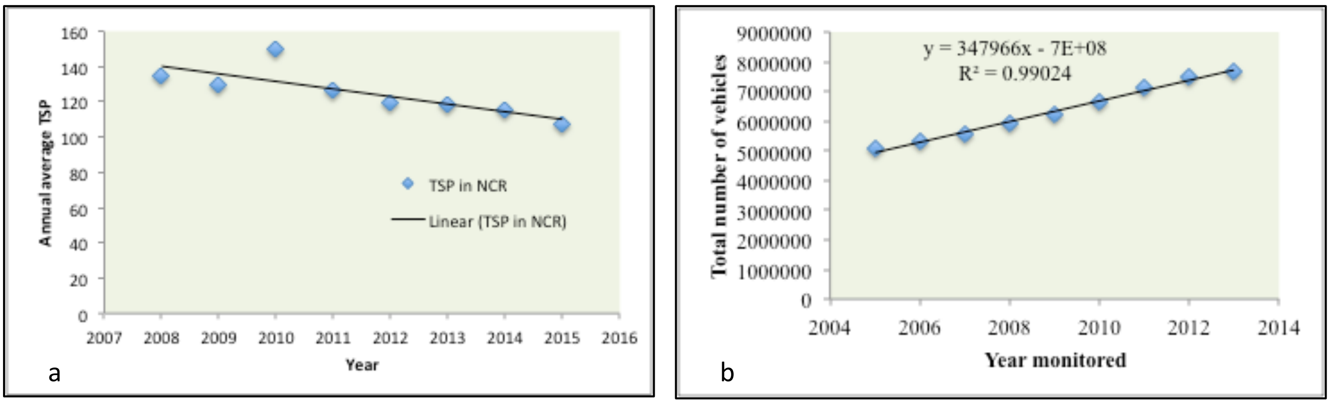

Figure 10. Air quality proxy a) TSP trend in NCR and b) Regression matrix of vehicle registered vs. year monitored (raw data sources: psa.gov.ph; denr.gov.ph)

Data from the Philippine Statistic Office on the 'Emissions of Greenhouse Gasses and Air Pollutants' showed increasing trend of stationary, mobile, and area air pollutant by composition (see **Fig.11**). Stationary pollutants coming mainly from fossil fuel combustion showed higher levels of sulfur oxides (SOx), nitrogen oxides (NOx), and particulate matter (PM) (p – 2.45 x10-8; α – 95%). These chemical constituents are associated products of fuel combustion. Mobile sources also showed varied trends among air pollutants (p - 8.89 x 10^{-7} α – 95%) with overall increasing trend of carbon monoxide (CO), evidenced of incomplete combustion from vehicles. Volatile organic compounds (VOCs) and PM seconded CO for mobile air pollutant mainly coming from vehicles. The area source also showed varied difference among air pollutants (p - 1.84 x10-7; α – 95%) with higher levels of PM followed by NOx and CO in several occasions (see **Fig.9**). Overall, a trend on higher concentrations of NOx, CO, and PM were found in the data presented (**Fig.11**) triggering to form photochemical smog.

To draw association between air pollutants by source (mobile, stationary, and area), we consider statistical test using Pearson correlation between air pollutants to total vehicle acquisition in the Philippines. Available data were culled from PSA with common year of monitoring on 2009, 2012, and 2016. Overall, for stationary source, a strong correlation was found between vehicles registered to PM (r - 0.776) (see **Table.6**). For mobile source a strong correlation was found between vehicles registered to PM (r - 0.967), NOx (r – 0.825), and VOC (r – 0.873) (see **Table.7**). For area source a strong correlation was found between vehicles registered to PM (r - 0.857) whereas inverse correlation was found with other air pollutants (see **Table.8).** Present findings corroborated the results of site or regional specific studies of air quality in the Philippines mainly attributed to vehicular diesel emission as evidenced by high PM concentration (Cassidy *et al*., 2007; Gibe and Cayetano, 2017; Alas *et al*., 2018).

On the other hand, some studies showed air pollution caused by disposal sites. One is the carbon dioxide (CO2) emission contributing to greenhouse gas emission in two landfills in Negros Oriental (Caballero, 2014). Second, were the findings of Lamorena-Lim and Rosales (2016) on the presence of lead and cadmium in air TSP in Payatas dumpsite, NCR. This corroborated the findings of Bagtasa *et al*. (2018) with solid waste burning and other anthropogenic sources influenced the total air fine particulate in Northwestern Philippines by 34% contribution. Likewise, previous findings of Gibe and Cayetano (2017) also showed the input from agricultural waste burning to PM air deposition. Overall, this section presents the air pollution burden brought by population increase via increased vehicular and waste emissions.

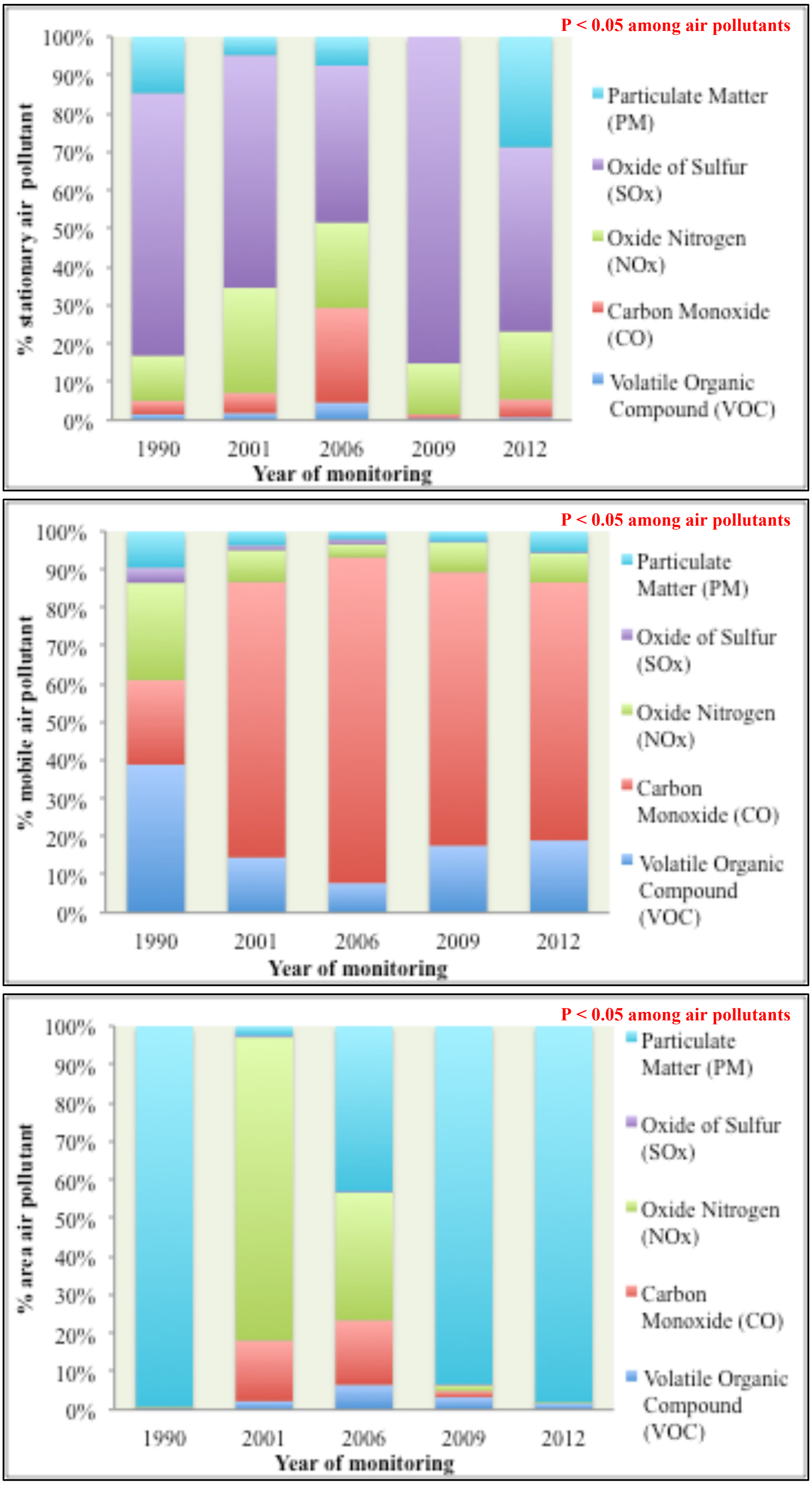

Figure 11. Percent composition of air pollutant by source in the Philippines on 19900-2012 significant at α – 95% (p <0.05); (raw data source: psa.gov.ph)

Table 6. Pearson correlation matrix of stationary air pollutants to total no of vehicles (2009, 2012, and 2016)

Variables	Total vehicles	VOC	CO	NOx	SOx	PM
Total vehicles	**1**	-0.791	-0.721	-0.423	0.054	0.776
VOC	-0.791	**1**	0.994	0.889	-0.654	-0.227
CO	-0.721	0.994	**1**	0.933	-0.731	-0.123
NOx	-0.423	0.889	0.933	**1**	-0.928	0.243
SOx	0.054	-0.654	-0.731	-0.928	**1**	-0.587
PM	0.776	-0.227	-0.123	0.243	-0.587	**1**

VOC – volatile organic compound; CO –carbon monoxide; NOx – nitrogen oxides; SOx – sulfur dioxides; PM – particulate matter (raw data source: psa.gov.ph)

Table 7. Pearson correlation matrix of mobile air pollutants to total no of vehicles (2009, 2012, and 2016)

Variables	Total vehicles	VOC	CO	NOx	SOx	PM
Total vehicles	**1**	0.873	-0.921	0.825	-0.848	0.967
VOC	0.873	**1**	-0.994	0.996	-0.999	0.721
CO	-0.921	-0.994	**1**	-0.980	0.987	-0.792
NOx	0.825	0.996	-0.980	**1**	-0.999	0.654
SOx	-0.848	-0.999	0.987	-0.999	**1**	-0.685
PM	0.967	0.721	-0.792	0.654	-0.685	**1**

VOC – volatile organic compound; CO –carbon monoxide; NOx – nitrogen oxides; SOx – sulfur dioxides; PM – particulate matter (raw data source: psa.gov.ph)

Table 8. Pearson correlation matrix of area air pollutants to total no of vehicles (2009, 2012, and 2016)

Variables	Total vehicles	VOC	CO	NOx	SOx	PM
Total vehicles	**1**	-0.962	-0.860	-0.836	-0.995	0.857
VOC	-0.962	**1**	0.966	0.954	0.984	-0.965
CO	-0.860	0.966	**1**	0.999	0.905	-1.000
NOx	-0.836	0.954	0.999	**1**	0.884	-0.999
SOx	-0.995	0.984	0.905	0.884	**1**	-0.902
PM	0.857	-0.965	-1.000	-0.999	-0.902	**1**

VOC – volatile organic compound; CO –carbon monoxide; NOx – nitrogen oxides; SOx – sulfur dioxides; PM – particulate matter (raw data source: psa.gov.ph)

3.4.2 Land based pollution

3.4.2.1 Solid waste impacts to land

On the other hand, the issue of land-based pollution in the Philippines is mainly due to improper solid waste disposal. This accounts to the use of unregulated landfills and dumpsites owing to lack of institutional arrangements, unwillingness of stakeholders, and convenience of dumping although other alternatives are available (Galarpe & Parilla, 2012; Galarpe & Parilla, 2014a; Galarpe & Parilla, 2014b; Galarpe, 2015; Galarpe, 2017). Noteworthy to extrapolate that growing population with inefficient system to process waste management may result to land based solid waste deposition. Primarily solid wastes are characterized as structural pollutant upon leaching in land surface may release toxic chemical constituents. **Fig.12a** (Galarpe, 2017) presents the regions with highest solid waste generation in the Philippines on 2012-2016 culled from DENR-EMB National Solid Waste Management Commission report. Overall trend showed higher waste generation in NCR, 4a, and 3 considered regions with high population and urbanization. The **Fig.12b** present a significantly linear correlation (r- 1; p – 8.86 x10^{-11}) between projected population-medium assumptions to annual projection of solid waste volume on 2012-2016. The overall trend provides a statistical notion that population drives solid waste generation which may be poorly unmanaged true among developing counties.

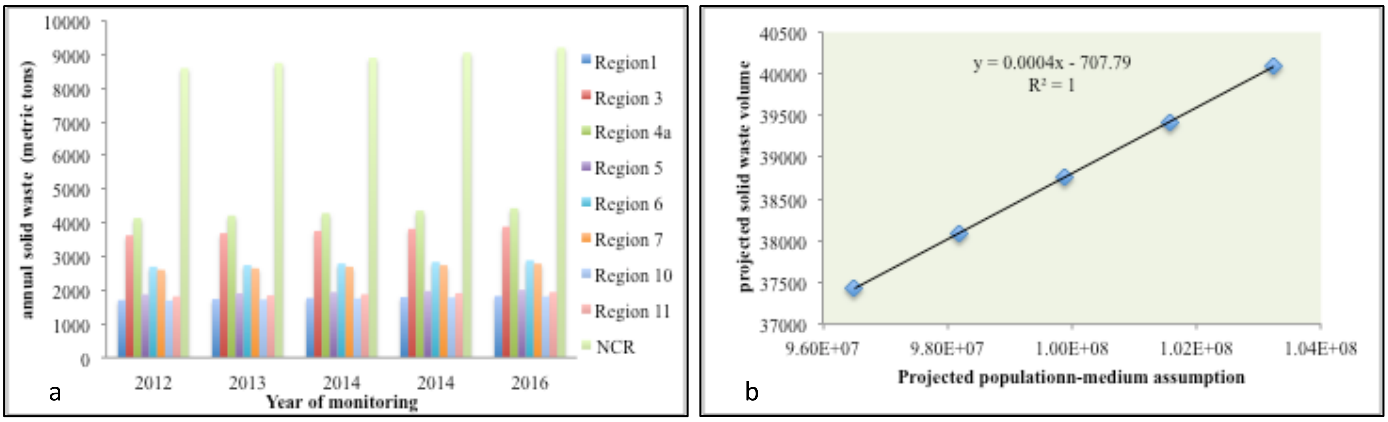

Figure 12. Solid waste status in the Philippines a) volume generation annually and b) correlation map between projected population-medium assumption and projected annual solid waste generation; significant at α – 95% (p<0.05) (raw data sources: psa.gov.ph denr.gov.ph)

Table 9. Environmental impacts brought by disposal sites in the Philippines (Galarpe, 2017)

Dumpsite/ Landfill	**Location**	**Impacts to**	**Findings**	**Reference studies**
Cebu City Sanitary Landfill	Region 7 Cebu City	Water	TDS Total coliform Total Cd and Pb were beyond the standard	Galarpe and Parilla (2012) Galarpe and Parilla (2014a)
Payatas dumpsite	NCR, Quezon City	Water	Total coliform exceeded the standard high levels of TDS, TSS and total coliform and low pH levels	Su (2005) Su (2008)
Rodriguez Landfill	NCR Rodriguez, Rizal	Water	Sporadic contamination of isotopes from leachate	Castañeda *et al.* (2012)
Bais landfill	Negros Oriental	Water	Total coliform exceeded the standard Pb 0.022-0.057 ppm	Caballero (2014)
Bayawan fandfill				
Cebu City Sanitary Landfill	Region 7 Cebu City	Soil	Hg in soil (0.238 ppm) higher than the world median (0.05 ppm)	Buagas *et al.* (2015)
Zayas landfill	Region 10 Cagayan de Oro	Soil	Highest recorded level of Hg was 0.164 ppm	Dy *et al.* (2013)

3.4.2.2 Heavy metals in soil

The unlikely impacts of waste disposal to soil was studied by Buagas *et al*. (2015) and Dy *et al*. (2013) elucidating mercury contamination (see **Table.9**). This is alarming given metals absorbance to plant, volatilization to air, and leaching to water bodies. Some of the contaminants may leach from the waste to soil then to water tables during precipitation, consequently affecting adjacent water bodies to disposal sites (see **Table.9**). Water pollution brought by disposal site is elaborated in the next section.

Heavy metals in soil adjacent to electronic waste shops in Metro Manila showed a mixture of serious pollutant metals (Ni, Cu, Pb, and Zn) and Cd (polluted modestly) in formal dust form (Fujimori *et al*., 2012). A follow up study particularly found elevated concentrations of copper, zinc, and lead which were distributed discretely in surface soil (Fujimori and Takigami, 2014). This was also corroborated by the previous study in Metro Manila, NCR by Solidum (2008) with lead concentrations in plant species (0.25 to 17.36 mg/kg) and soil samples (83.74 to 183.51 ug/g). In general, highly urbanized or populated areas with higher fuel combustion emissions were found to likely have contaminated soils brought by anthropogenic input.

3.4.3 Water quality issues

Selected studies in the Philippines showed water quality pollution in highly populated areas via release of untreated domestic wastewater and industrial discharges. Reports of heavy metals and nutrient loading in bay areas (Velasquez *et al*., 2002; Prudente *et al*., 2007; Chang *et al*., 2009; Galarpe *et a*l., 2017), organic load in river waters (Flores *et al*., 2012; Maglangit *et al*., 2014; Maglangit *et al*., 2015) and contamination of deep wells adjacent to disposal sites (Su, 2007; Su, 2008; Galarpe and Parilla, 2012; Galarpe and Parilla, 2014a- **Table.9**) were some of the water quality related studies in the country showing pollution input. Disposal sites also have water polluting potential as studied in the Philippines particularly (see **Table.9**) with lead, coliform, total dissolved solids, and radio isotopes (Su, 2005; Su, 2008; Galarpe and Parilla, 2012; Castañeda *et al*., 2012 Dy *et al*., 2013; Galarpe and Parilla, 2014a; Buagas *et al*., 2015).

This corroborates the DENR EMB (2006-2013) national water quality status report with poor rating on river waters DO (12%), BOD (12%), and phosphates (44%) whereas coastal-marine waters had poor rating for total coliform (35%) and fecal coliform (54%). PSA data of Class C rivers on 2006-2015 likewise showed increasing BOD concentrations among highly urbanized regions in the country (see **Fig.13**). NCR ranked highest with the recent BOD data followed by Regions 7, 3, and 6. Most of these rivers traverses major cities in the assessed regions consequently may act as sink for organic loads from domestic and commercial sewages. Overall, usage and disposal of water resources are dominant environmental ill effects brought by population growth.

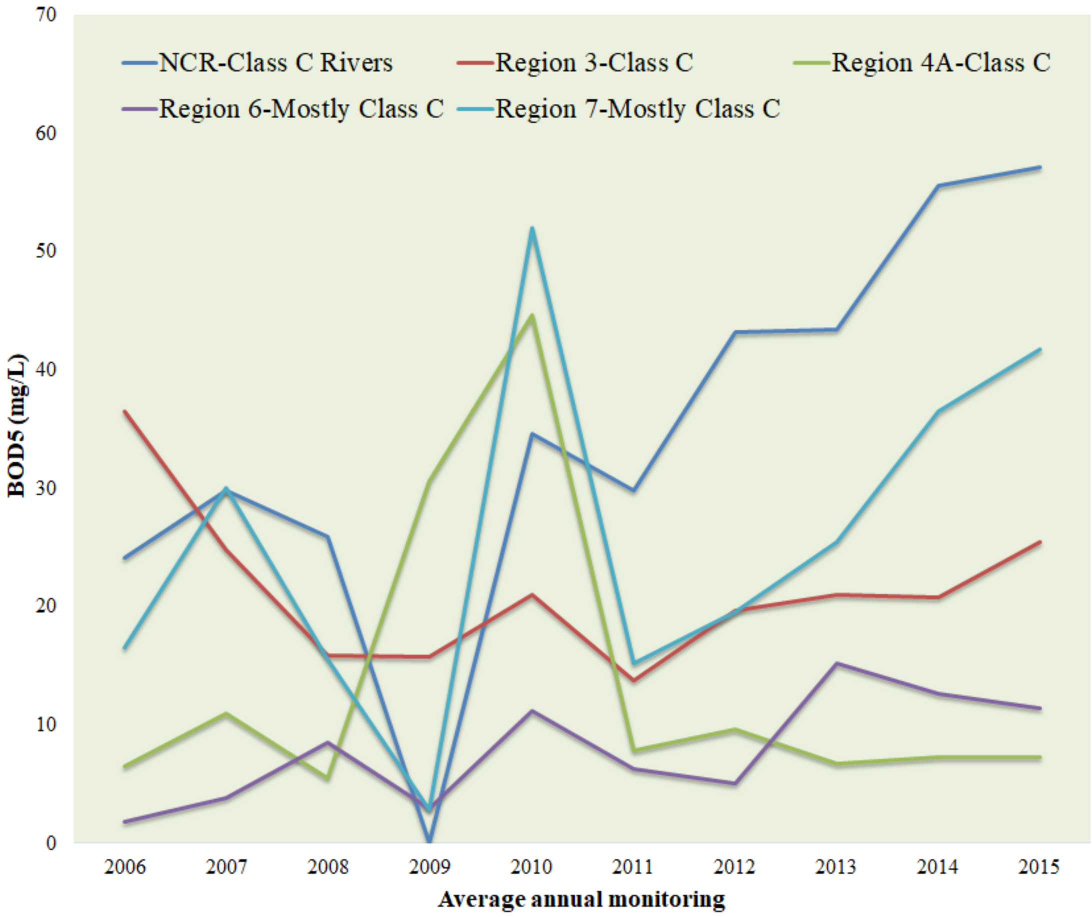

Figure 13. Annual average BOD5 concentration of inland rivers in selected regions (Class C water; (i) Fishery Water for the propagation and growth of fish and other aquatic resources; (ii) Recreational Water Class II. (Boatings, etc.); (iii) ndustrial Water Supply Class I. For manufacturing processes after treatment) (raw data sources: psa.gov.ph; denr.gov.ph)

3.4.4 Health implications

At the latter, humans are likely to suffer pollution load incurred to the environment. In my co-authored paper under review (Estenzo *et al.*, 2017 (completed year of study), we found strong association between PM10 and cases of URTI (Upper respiratory tract infection) in Cagayan de Oro, Philippines on 2016. Regardless of other factors like temperature and precipitation having a causal influence on URTI cases, the overall trend between PM10 and URTI were found significant (p - 0.0253). This may be a good proxy to elucidate causal loop of population to environment and vice versa. Likewise, data from DOH (2000) showed significant estimates of water-borne diseases like diarrhea, cholera, typhoid, paratyphoid, and hepatitis A. Estimates showed 500,000 morbidity cases and 42, 200 mortality cases with incurred health costs (Worldbank, 2003). Land based pollution owing to solid waste compromising human health is unexplored, however selected studies of adjacent communities to disposal sites in the country showed cases of URTI, gastrointestinal symptoms, and dermal infections (Su, 2005; Su, 2007; Nazareno *et al*., 2013; Dimaampao *et al*., 2014; Ejares *et al*., 2014; Galarpe and Parilla, 2014b; Galarpe, 2015) (see **Table.10**). Present review supports population projection of Lutz *et al*. (2001) with the emergence of new diseases owing to unrelenting population growth.

Table 10. Summary of health responses from community adjacent to disposal sites (Galarpe, 2017)

Disposal Site and Location	Findings	Reference studies
Cebu City Sanitary Landfill, Cebu, Region 7	Gastrointestinal upper respiratory skin diseases dengue	Galarpe and Parilla (2014 b) Nazaero *et al*. (2013)
Umapad dumpsite, Mandaue City, Region 7	Upper respiratory and skin diseases	Ejares *et al*. (2014)
Lapu-lapu City dumpsite, Region 7	Gastrointestinal and upper respiratory health response	Galarpe (2015)
Zayas landfill, Cagayan de Oro Region 10	Dengue cases	Dimaampao *et al*. (2014)
Payatas dumpsite, Quezon City	Prevalence of diarrhoea and water borne illnesses	Su (2005) Su (2007)

3.5 Mitigating measures

The environmental burden brought by population even at lower growth rate may have disproportionate impact related to pollution (Pimentel *et al*., 1999; Harte, 2007). Further projection studies also revealed the unlikelihood of doubling population (Lutz *et al*., 1997; Lutz *et al*., 2001). Thus, giving rise to intervening factors to sustain the environmental goods and services despite the growing population. This section particularly highlights the optimistic reviews on how the Philippines may draw example to mitigate population impacts to the environment.

3.5.1 Education, and science & technology

Education, and science & technological interventions are essential players to lay logical considerations to mitigate exacerbating environmental ill effects brought by population. The increasing literacy among Filipinos (see **Fig.14**) presents promising socioeconomic benefit despite the growing population. The influence of education to population has long-term environmental dividends increasing consciousness for conservation and perception towards social issues. Selected studies on Filipinos environmental awareness like waste management (Abne *et al.*, 2017; Galarpe and Heyasa, 2017) showed favorable responses. This is viewed as positive indicator that there is public interest towards environmental conservation and institutional policies must reinforced these proactive behaviors.

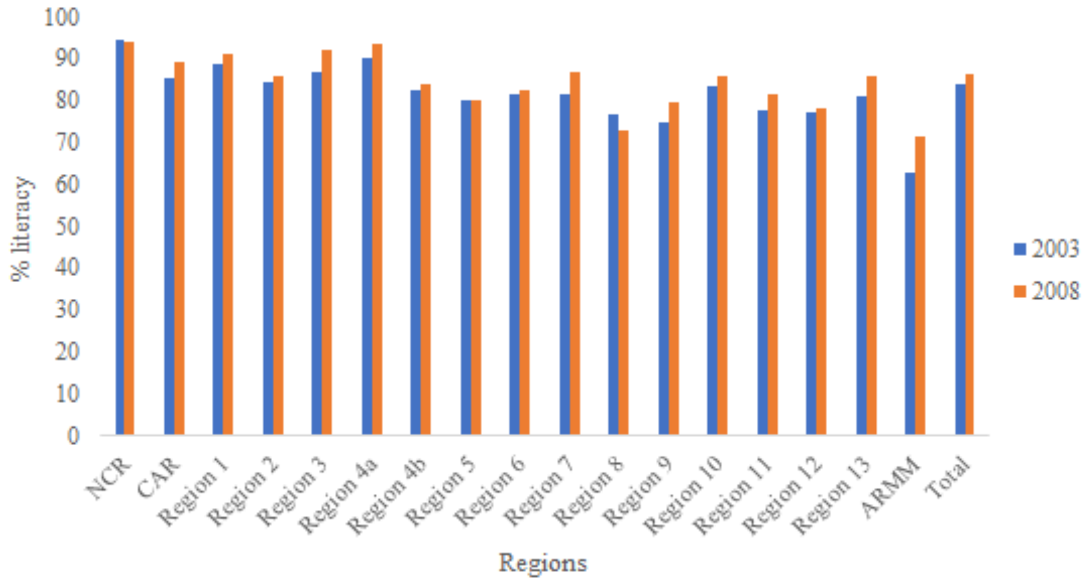

Figure 14. Functional literacy of Filipinos by region ages 10-64 years old on 2003 and 2008 (raw data source: psa.gov.ph)

Environmental education for instance may influence society to generate new leaders with proactive environmental behavior (Hudson, 2001). Also, population with sufficient knowledge is capable of producing invention and adoption to new technologies (Southgate, 2009) at the latter be used to provide solutions. This may include shifting towards alternative energy resource (Pimentel *et al.*, 2010) and agricultural biotechnology (Southgate, 2009) to maximize agriculture in sustaining growing population. Likewise, affluence and technological diffusion are key concepts for environmental transition to also benefit society with innovations brought by pollution input from human activities (Goklany, 2009). Overall, the benefits from this mitigating factors emanates from educating the public for alternative fertility option and its environmental-economic benefit. Giving the public the opportunity to learn environmentally sounding behavior through environmental outreach and formal education in schools (Bjorkland and Pringle, 2001; Aguilar *et al*., 2008) as options to promote proactive conservation efforts.

3.5.2 Institutions and policy content

Institutional arrangements enabled policy implementation like the case of solid waste management in the Philippines (Ancog *et al*., 2012; Galarpe and Parilla, 2014b; Galarpe, 2017). This policy-institution linkage to address pollution is a classic example of how each linkage component must complement to address environmental problem, a failure of the other is a failure of the entire linkage. Nonetheless, we may draw example here on how to address environmental impacts brought by population.

The paper of York *et al*. (2003) highlights the need for sound science in driving environmental policy and that plasticity analysis be used to guide policymakers toward identifying and prioritizing environmental problems most responsive to policy solution. For example, the decline in world population projection estimates the same is true in the Philippines indicates the success of policy intervention cascaded through institutions. Slow fertility in present population is anchored from policy enforcement of providing available resources for family planning and importantly human rights framework (Potts, 2007; Lutz *et al*., 2001). Likewise, the remaining aging population of working class may be provided with economic opportunities like establishing microfinance industries to increase GNI (Abrigo *et al*., 2016; Agbola *et al*., 2017). Peculiarly, the Philippines benefited from this decline in fertility rate and increase in working class population (Abrigo *et al*., 2016), with the aim of reducing population growth rate and alleviate poverty.

The Philippines policy and institutions to address environmental impacts like pollution are all in placed. This included policies on waste management (both solid and hazardous), environmental quality (clear water and air acts), and conservation cascaded through government agencies. However, the gap in fully enforcing the policy-institution linkage is the lack of baseline data drawn from sound science. This is compounded by the lack of interagency collaborations and making data more available to public to address environmental problems. If these constraints are addressed perhaps a better policy-institution linkage be able to enforce in the Philippines. Overall, this section presents how policy and institution may complement to address environmental impact brought by population. A policy without enabling institution and institution without a policy basis cannot enforce.

3.5.3 Socio-economic factors

The paper of O'Toole (2009) laid the foundation of exurbanite, where the emphasis is on building socioeconomic opportunities of all income groups peripheral to urban areas. This is often coined to decentralization where the emergence of business districts, manufacturers, and industrial plants may be situated in rural areas. This will create economic gain in a growing population thus reducing urban opportunity dependence and urban sprawl. Equitable resource access and reduction in migration pattern in the entire country will be expected as economic opportunities spreads out in the country.

Also, a regional based economy will reduce poverty and dependence of population to national aid and services. Regional economy or decentralization approach provides resilience to environmental perturbations like typhoons and earthquakes. Likewise, a low carbon atmospheric emission may decrease inevitably owing to reduce fuel transportation cost and emissions of goods and services. This is in agreement with the decomposing method analysis of Fujii (2017) where regional based application may best fit for poverty alleviation.

Also, the Philippines must take advantage of the dividends from its shifting population age structures that are increasingly concentrated towards productive ages (Abrigo *et al.*, 2017). This corroborated the data presented by Racelie *et al.* (2011) with the Philippines employed age group and labor force participation at the productive age (see **Fig.15**). Overall, the advance population demographics have positive socioeconomic benefit in the Philippines (Ogawa, 1982). If the country's policy is continually enforced on family planning and fertility options we may benefit socioeconomically.

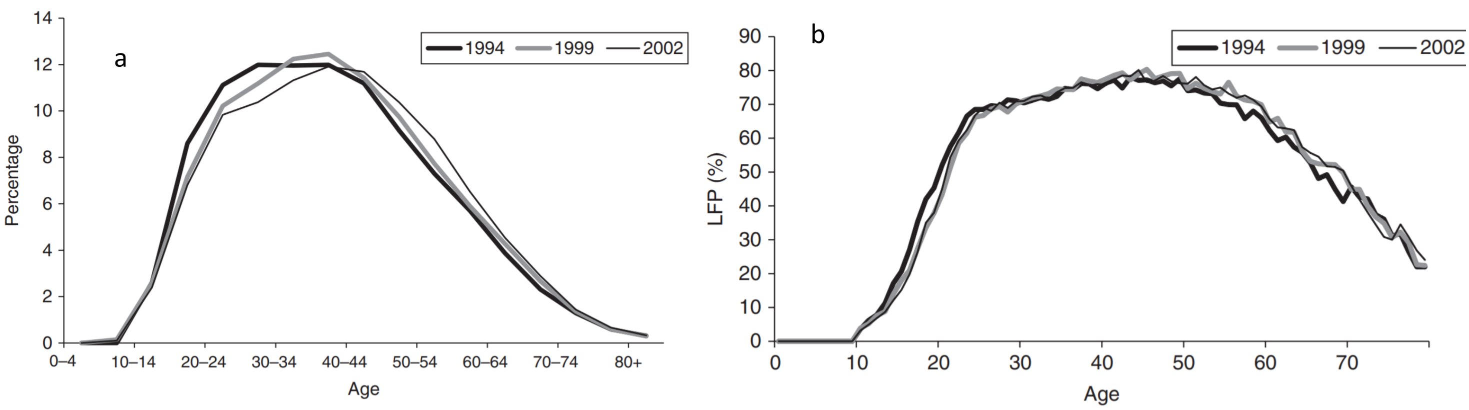

Figure 15. a) Distribution of employed persons by age: Philippines, 1994, 1999, and 2002; b) Labor force participation by age: Philippines, 1994, 1999, and 2002 (Racelis *et al.*, 2011)

4. CONCLUSION

Overall, the Philippines increasing population have inflicted the environment from resource extraction to release of pollutants as by-products. This paper particularly highlights the energy resource demand, landuse shift-forest cover loss, agricultural productivity, and environmental quality-pollution issues as key environmental problems burdened by population. Findings from qualitative analysis of reviewed journals indicate changing environmental quality of the Philippines ranging from fuel demand, forest cover loss, air emissions, water pollution, and at the latter brought public health concerns. This was corroborated with the statistical analysis correlating population at medium assumption to selected environmental matrices (resource and pollutants). The demand to sustain growing population need for food and economic opportunities exacerbate environmental ill effects. These ecological constraints may be addressed if the Philippines institutional systems expedite the application the sound science education, affluence, and technology to lay mitigating measures. Considering peaking of fossil fuel, the country must consider alternative energy options to catalyze environmental revolution cascading opportunities and proactive environmental behavior. Decentralization of urban areas and providing market incentives in the urban peripheries provides equitable access to resources essential to support the current demographic shift. The country must take advantage given the favorable population demographic shift, with more working class citizen and better family planning alternatives. Present review is preliminary and provides a baseline context of population influence to environment in the Philippines.

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