

Potential Use of Substance Flow Analysis to Recount the Nitrogen Flux in Agriculture Soils System in Terengganu

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ABSTRACT

The Substance Flow Analysis (SFA) concept has been widely used for the sustainability of material flow management in agriculture of many South-east Asia studies including Malaysia. Focusing on agricultural land, this paper emphasises the dynamic analysis of nitrogen flux from sectors, processes and flows that enter, leave, circulate and also accumulate in the metabolism of agricultural land. SubSTance Flow Analysis software (STAN 2.5) and Microsoft Excel have been used to complete the nitrogen equilibrium calculation in four selected subsystems which are subsystem market use, crop production, livestock production and environment, in six districts in Terengganu. In the present study, intensive use of nitrate fertilisers (5835 tons N per year), crop harvesting (3645 tonnes per year), and water absorbing into underground systems (1969 tons per year), have been identified as the major contributors to environmental degradation. The results of the present study found that the SFA method is very practical to estimate the amount of agricultural nutrient load, to identify the contribution of agricultural activity, the level of land use, and also to analyse the pattern of agricultural nutrient release space in Terengganu. Some innovative proposals are also offered and hopefully this study can be used as a reference for any sustainable management plan for other scientific studies.

Keywords: Substance Flow Analysis (SFA), nitrogen (N), agriculture soil, Terengganu, sustainability.

INTRODUCTION

Nitrogen is an important element needed to complete environmental sustainability from a micro perspective. Nitrogen which comprises 78% of atmospheric gases is also the most important element in protein sources for earth's life and has provided major support to the productivity of the food chain (Ghaly and Ramakrishnan 2015). However, increasing nitrogen concentrations in the environment can lead to catastrophic crises such as surface water eutrophication, nitrate pollution in soil, soil acidity and greenhouse gas emissions (Gu *et al.* 2015; Nettles *et al.* 2016; Nguyen *et al.* 2016). The soil containing enough nitrogen molecule markers is important to complete the nutrient cycle, organic matter decomposition, residual degradation, nutrient transformation, atmospheric composition, water quality and plant productivity (Alvares-Martin *et al.* 2016; Zheng *et al.* 2016; Coleman *et al.*,

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2004). Leilei *et al.* (2018) found soil respiration, both autotrophic respiration and heterotrophic respiration, to be the major contributor to controlling carbon dioxide in the atmosphere. Galloway *et al.* (2008) and Poschenrieder *et al.* (2008), on the other hand, found that atmospheric deposition, due to fossil fuel burning since the industrial revolution, has contributed to soil acidity and directly to toxicity in soil organisms and plant roots. However, the allocation of nitrogen reduction under the soil ecosystem can also be affected by cation toxicity, loss of mineral cation and ammonium toxicity (Van den Berg *et al.* 2005 Spelling in ref different) Bowman *et al.* 2008; Tian *et al.* 2015; Tian and Niu 2015). In response to these above-mentioned factors, the investigation of application of synthetic nitrogen fertilisers and leguminous cultivation at the initial release of the material is crucial to understand its relation to the entire chain of agricultural land ecosystems. This requirement is in line with the discovery by Andrian (2017) who stated the fertiliser application of synthetic nitrogen fertiliser and manure and the increase in anthropic pressure in the agro-system should be understood on a detailed molecular scale. Explanation on the existence of nitrogen flow underground and on the ground organs is essential to improve sustainable agriculture.

Substance Flow Analysis (SFA) is a tool used to measure the flow and stock of materials in different and changing spatial space units (Senthilkumar *et al.* 2012 and Zhang *et al.* 2017). SFA detects nutrients that flow and manages the nutrients flow in a more sustainable, efficient and systematic recovery system. However, Li *et al.* (2013) found that SFA techniques have limitations in measuring trajectory of long-term changes and include external control factors such as temperature regimes, crop rotations, rainfalls, trade tariffs, farm inputs, fertiliser subsidies and others. The efficiency of SFA utilisation can be further enhanced through a longer period of regular inspection and by taking into consideration more suitable variables depending on the socio-economic changes in a study area. SFA calculates the nutrient outflow mechanism at the release point based on the spatial and the non-spatial inventory databases at village, city, local, national and global agglomeration scale (Chen *et al.* 2010; Bouwman *et al.* 2013). Although the uniqueness of the SFA approach is often expressed in industrial ecology (Montangero *et al.* 2007; Cencic and Rechberger 2008; Schaffner *et al.* 2009), some researchers have successfully expanded their research into nitrogen chain in agricultural land. Most of the studies illustrate the excessive, or the decrease and stagnant nitrogen flows in the study environment (Bashkin *et al.* 2002; Chen *et al.* 2010; Gronman *et al.* 2016). Some quantitative assessments of the nitrogen cycle have been carried out by Jiang and Yuan (2015) and Liu *et al.* (2016). However, there is still no local study recorded yet that provides an integrated understanding of the nitrogen flow in agricultural land and its environment using SFA techniques. Therefore, the SFA's role in investigating the nitrogenous traces that enter, are lost and leave the environment, can lead to the formation of a potential nitrogen pollution index in Terengganu. Ma *et al.* (2010) calculated nitrogen using the SFA method and successfully developed Model NUFER (Nutrient Flow in the Food Chain, Resource and Environmental Management). York *et al.* (2003)

and Wang *et al.* (2013) also successfully developed Model INFA (Integrated Nutrient Flow Analysis) and Model STRIPAT (STochastic Impacts by Regression on Population), Affluence and Technology, which proves that there is nitrogen change in agricultural land due to human destruction. The objective of this study is to measure and to interpret changes of nitrogen flow in the nutrient management system and subsequently present its results for the state of Terengganu, Malaysia.

MATERIALS AND METHODS

In situ and ex situ data collection was conducted over a continuous 12-month period using resources from six agricultural areas of Kemaman, Dungun, Marang, Setiu, Besut, Hulu Terengganu, Terengganu with the data being primary, secondary and tertiary. The study focused on crop production and livestock systems. The overall study applied the Substance Flow Analysis (SFA) method introduced by Brunner and Rechberger (2004) to calculate nitrogen inputs, outputs and stocks. Meanwhile, STAN, short for subSTance flow ANalysis software, has been used to create a system of material flow in the form of substance and mass to nutrient management in this research study. Besides this, there are five important steps in generating the material flow modeling framework, which are as follows: System Analysis, Model Approach, Data Acquisition, and Simulation of the Results and Uncertainty Analysis. The detailed explanation for the implementation of the SFA method for some important variables is shown in Table 1. Basically, the calculation of nitrogen flow is derived from the value of the material flow rate multiplied by the nitrogen concentration. Most of the material and the nitrogen inventory databases were collected from several sources such as statistical databases at government, state and private agencies, theses, journal articles, government reports, consultations and interviews with experts and farm entrepreneurs as well as raw data collection in the study area.

RESULTS AND DISCUSSION

Recounting the Nitrogen Loads in Soil System

From the SFA method, a total of 9,817 tons of N per year has been recorded in the subsystem of agricultural land use. It is estimated that 75% of nitrogen is in the subsystem of crop land use. The remaining 25% is identified in the subsystem of farming activities. The results for the nitrogen balance are based on the current input rate of nitrogen at the initial stage of the subsystem. The findings from the several official interviews and data collection indicate that most of the agricultural land in the study area is of BRIS Land Series which can be divided into several sub series : Baging, Rhu Tapai, Rudua, Jambu, Rusila and Merchang (Armanto *et al.* 2013; Usman *et al.* 2013; Paramanathan, 2000; 2017 (Not in ref list)). Much of the land use for commercial agricultural cultivation is carried out in peat and lowland soil. Figure 1 shows the nitrogen flow in the agricultural land of the study area.

TABLE 1
Mathematical equations for nitrogen input and output

Mathematical equations for nitrogen input	Mathematical equations for nitrogen output																		
<u>Inorganic fertiliser (IN1_Fer)</u> $IN1_Fer_{allcrop} = FN + £1Fni + £2Fnc$ $IN1_Fer_{allcrop}$ = Total amount of N fertiliser in the fields FN = Amount of original accumulation of N in the fields Fni = N applying Fnc = Amount of employed compound fertiliser £1, £2 = Proportion of pure N in the Fni and Fnc The N input from chemical fertilisers for every crop was estimated based on the formula given above. Examples of fertilisers considered were ammonium sulphate, potassium nitrate, urea (NPK), etc. The value of N input from fertilisers was multiplied by two seasons because the farmers normally applied fertilisers during these times. The data for the proposed fertilisation based on crop types were obtained from the Department of Agriculture Terengganu, as presented in Table a below. Table a: Series of guidelines for N fertiliser <table><tr><th>Variables</th><th>Mean of N Concentration (kg/ha/yr)</th></tr><tr><td>Paddy</td><td>139</td></tr><tr><td>Rubber</td><td>191</td></tr><tr><td>Palm Oil</td><td>230</td></tr><tr><td>Sugarcane</td><td>100</td></tr><tr><td>Maize</td><td>130</td></tr><tr><td>Other Crop</td><td>120</td></tr><tr><td>Fruits</td><td>60</td></tr><tr><td>Vegetables</td><td>80</td></tr></table>	Variables	Mean of N Concentration (kg/ha/yr)	Paddy	139	Rubber	191	Palm Oil	230	Sugarcane	100	Maize	130	Other Crop	120	Fruits	60	Vegetables	80	<u>Crop Harvested (OUT1_Hp)</u> $Hp_{allcrop} = FN + £1Fni + £2Fnc$ $OUT1_Hp_{allcrop}$ = Total amount of N fertiliser in the fields FN = Amount of original accumulation of N in the fields Fni = N applying Fnc = Amount of employed compound fertiliser £1, £2 = Proportion of pure N in the Fni and Fnc N loss from harvesting in TAS was calculated using the formula given above. The quantities of harvested crops (e.g. grains, root crop, legumes, fruit crops, vegetables, and industrial crops) were multiplied by respective nitrogen uptake coefficient.
Variables	Mean of N Concentration (kg/ha/yr)																		
Paddy	139																		
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<u>Organic fertiliser (IN2_mn)</u> $IN2_allmn = \sum_{i=1}^m ni \cdot pi \cdot ai \cdot 365$ $IN2_allmn$ = Volume of N in livestock manure ni = Amount of each species of livestock pi = Volume of excretion of each species per day ai = t Rate of collection and utilisation The N coefficient can be seen in Table b above. The calculation for organic fertiliser application rate based on the animal manure only took into account the manure left on the field during grazing. The ratio of organic fertiliser frequently used by farmers in research area consisted of cattle manure (81%) and chicken manure (19%). To formulate this input, the field of input manure = 1.7 kg/ha/yr was added into attribute Table b. Table b: Guidelines series for N fertilisation <table><tr><th>Code</th><th>Species</th><th>N concentration (kg/head/day)</th></tr><tr><td>IN2_mn_{buffalo}</td><td>Buffalo</td><td>0.0020</td></tr><tr><td>IN2_mn_{cattle}</td><td>Cattle</td><td>0.0020</td></tr><tr><td>IN2_mn_{goat}</td><td>Goat</td><td>0.0024</td></tr><tr><td>IN2_mn_{sheep}</td><td>Sheep</td><td>0.0020</td></tr><tr><td>IN2_mn_{poultry}</td><td>Poultry</td><td>0.0023</td></tr></table>	Code	Species	N concentration (kg/head/day)	IN2_mn _{buffalo}	Buffalo	0.0020	IN2_mn _{cattle}	Cattle	0.0020	IN2_mn _{goat}	Goat	0.0024	IN2_mn _{sheep}	Sheep	0.0020	IN2_mn _{poultry}	Poultry	0.0023	<u>Crop Residue (OUT2_Bcr)</u> $OUT2_Bcr_{allcrop} = \sum_{j=1}^m OUT2_j \cdot C_j$ $OUT2_Bcr_{allcrop}$ = Total biomass crop straw/residue output $OUT2_j$ = Quantity of the type of biomass m = Number of different type of crops C_j = Proportion of N per unit of a type of straw Nitrogen loss from harvested agricultural wastes disposal was calculated using the formula given above. The agricultural wastes were left in the field where they decomposed or grazed by cattle, buffalos, or goats. Only the straws are assumed to have left the case system through external use.
Code	Species	N concentration (kg/head/day)																	
IN2_mn _{buffalo}	Buffalo	0.0020																	
IN2_mn _{cattle}	Cattle	0.0020																	
IN2_mn _{goat}	Goat	0.0024																	
IN2_mn _{sheep}	Sheep	0.0020																	
IN2_mn _{poultry}	Poultry	0.0023																	
<u>Wet deposition (IN3_Rn)</u> $IN3_Rn = 0.14 \cdot (rainfall)^{\frac{1}{4}}$ $IN3_rainfall$ in kg/ha/yr and rainfall in mm/yr. No specific data could be obtained on the atmospheric nitrogen-deposition for research area. The calculation to determine the total atmospheric deposition for TAS ecosystem was done based on the formula given above by Stoorvogel <i>et al.</i> (1993), and multiplied by the size of agricultural land in each district. Due to the long distance between the Terengganu region and heavy industries as well as the power plant, the atmospheric nitrogen deposition was assumed to be very low. Dividing this input with the size of TAS (60,520 ha), the N input from atmospheric deposition was estimated to be 0.05 g/ha. Using the above formula, the rainfall intensity in TAS was 1800 mm.	<u>Leaching losses (OUT3_Ll)</u> $Q = (PR - 0.2S)^2 - (R + 0.8S)$ where Q = Runoff (inches), R = Rainfall (inches), S = Potential maximum retention (inches) after runoff begins The calculation for the potential of nitrogen concentration loss in leachate was done using the formula given above by Smaling and Janssen (1993). The magnitude of leachate coefficient was 0.25 for clay and 0.5 for sandy soil in TAS (DOA-TRG, 2017). The average annual rainfall in the area being studied was about 1800 mm. The results of calculation are shown in the Table c below.																		

	Table c : The coefficient for N losses by each crops,		
	Code	Crop	N losses (runoff+erosion) in kg/ha/yr
	OUT3_LLpaddy	Paddy	6.5
	OUT3_LLrubber	Rubber	11.9
	OUT3_LLopalm	Oil Palm	6.5
	OUT3_LLmaize	Maize	8.9
	OUT3_LLsugarcane	Sugarcane	15.2
	OUT3_LLvegetables	Vegetables	4.5
	OUT3_LLcrops	Other Crops	11.9
	OUT3_LLfruits	Fruits	4.5
Nitrogen-fixation (IN4_Bnf)			
IN4_Bnf = $0.043 \times E$ IN4_Bnf = Amount of biological N fixation E = Economic yield of the leguminosae IN4_Bnf _{fixed} = $0.5 + 0.1 \times \sqrt{\text{rainfall}}$ IN4_Bnf _{nonmycorrhizal} = $\sqrt{\text{rainfall}}$			
The determination of symbiotic N-fixation rate by leguminous crops in TAS was done using the formula given above (Smaling <i>et al.</i> 1993). It was estimated that the percentage of N supply available in soil was 50%. The rest was diverted by the P availability in soil in TAS, which limited the N-fixation. The calculation for the N-fixation by soy, nuts, and legumes was done based on the size of area harvested for these crops, and then multiplied by average annual rainfall in the area, assuming that the rainfall in TAS was > 1300 mm and the average N-fixation by bacteria or algae was 30 kg/ha/yr.			
Gasses losses (OUT4_Gl) $N_2O_{(AWMS)} = \sum [N_{(T)} \times N_{ex(T)} \times AWMS_{(T)} \times EF_{(AWMS,T)}]$ where: AWMS = Animal Waste Management System $N_2O_{(AWMS)}$ = N_2O emission from a particular AWMS $N_{(T)}$ = Total number of animals of type T $N_{ex(T)}$ = N excretion from animals of type T (kg N/animal/yr) $AWMS_{(T)}$ = Fraction of $N_{ex(T)}$ for the type of AWMS containing animals of type T $EF_{(AWMS,T)}$ = N_2O emission factor for an AWMS (kg N_2O -N/kg N_{ex} in the AWMS) of animals of type T. The nitrogen denitrification process was calculated using the guideline and formula developed by IPCC (1996a,b) based on the function of basis transfer introduced by Stoorvogel <i>et al.</i> (1993). The nitrous oxide emission concentration coefficient from fertiliser and manure according to the types of crops are shown in the table below. It was assumed that the average N range was 1.20–78.48 g N_2O -N /ha/day. The results of calculation are shown in the Table below. Table d: Results of calculation of N gas losses by crop products in TAS			
	Code	Crop	NO _x Emission from F+M
	OUT3_LLpaddy	Paddy	1.25
	OUT3_LLrubber	Rubber	1.25
	OUT3_LLopalm	Oil Palm	1.25
	OUT3_LLmaize	Maize	1.25
	OUT3_LLsugarcane	Sugarcane	1.25
	OUT3_LLvegetables	Vegetables	1.25
	OUT3_LLcrops	Other Crops	1.25
	OUT3_LLfruits	Fruits	1.25

The Framework of the Nitrogen Flux Model

The nitrogen input and output flows that were taken into account in Terengganu's agriculture system are illustrated in Figure 2. The total nitrogen load recorded in 2017 was 15.81 kiloton N/yr. The nitrogen deficit in agricultural soil was estimated to be 2305 ton N/yr. The comparison between crop production and livestock production revealed that nitrogen loss was four times higher in the crop production system with 3109 ton N/yr compared with the livestock production system with 804 ton N/yr. This result correlated with the initial reading of the statistics, which only considered the nitrogen flow aspect in agricultural wastes such as crop residues and animal wastes.

For the nitrogen outflow from the crop production system, the findings show that the percentage of nitrogen accumulation was higher in the soil stock, which was 73% with 7495 ton N/yr, compared with the 26% with 2683 ton N/yr of nitrogen released into the water body. The nitrous gases emission into the atmosphere only accounted for 1% with 47 ton N/yr of the nitrogen outflow. In the crop production system, the highest nitrogen input was contributed by the

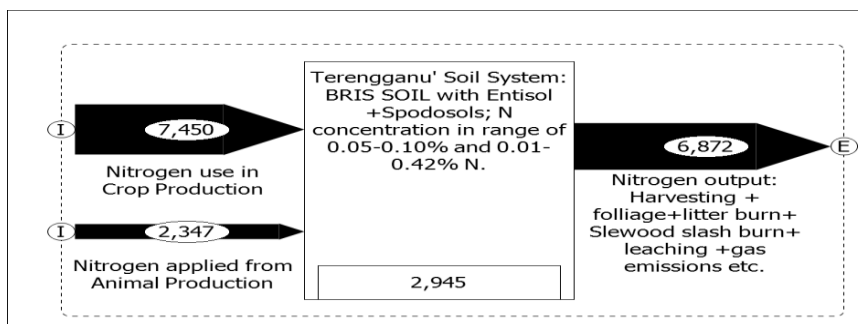


Figure 1: Nitrogen input and output in the soil system

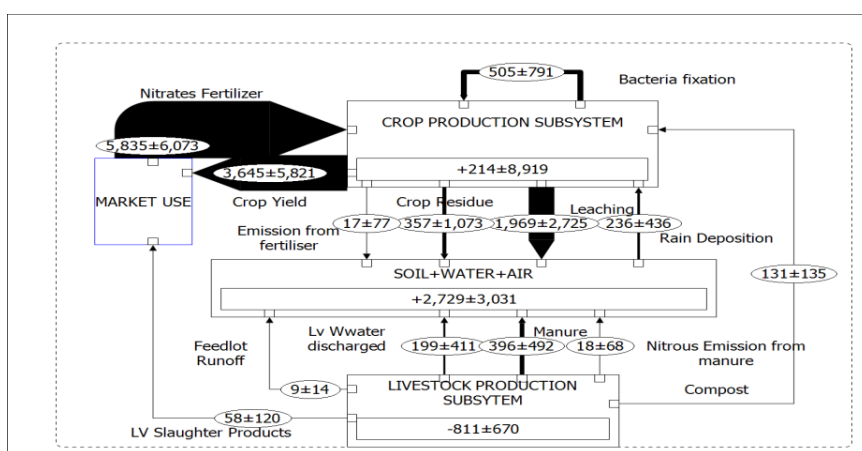


Figure 2: The SFA model for nitrogen flow in the agriculture system in Terengganu

application of nitrate-based fertilisers in cropping activities with 5954 ton N/yr, crop residues with 715 ton N/yr, and bacterial fixation with 648 ton N/yr.

The highest nitrogen load percentage from the livestock production subsystem released into the 'Environment' was into the soil stock especially plantation soil, at around 55% with 444 ton N/yr. Next came water and air at 39% with 315 ton N/yr and 6% with 43 ton N/yr, respectively. The release of animal waste and wastewater directly into the environment has emerged as the highest nitrogen flow input in the livestock production system, with the total amount being 749 ton N/yr. Based on the observation during the sampling activities in feedlot farms and traditional grazing farms, much of the nitrogen in livestock manure, carcasses, and slaughter wastes was not being reused and only 5 to 7% was recycled.

However, the production of nitrogen from import, export, household, and the food processing industry are excluded from this study. Further, inputs on atmospheric deposition, seed, human excreta, and irrigation that involve ammonification as well as nitrification, subsequently leading to denitrification,

plant absorption, and eutrophication, are not explained in this study because these inputs present insignificant and slow changes within this region.

Limitations

There are obviously some limitations to the data collected and calculated. Some factors such as changes in nutrient concentrations, changes in dry weight of livestock feeds and possibly the lack of statistical information from various sources do have an influence on the results of this study. For example, complexity occurs in the calculation of nitrogen in relation to fertilisation, soil decomposition, manure management and wastewater treatment because of nitrogen's tendency to escape into the air. Also, nitrogen calculation through leachate of agricultural soil is difficult to determine because there are differences in factors such as soil types, gradients and methods of cultivation.

The Tornado diagram in Figure 3 with the calculated results in Table 1 shows the variation of sensitivity towards nitrogen flow, based on four main variables: on fertilisers into soil, leaching of soil, crop yield, and crop residue. This nitrogen sensitivity analysis was able to identify that the nitrate chemical fertiliser application by farmers is the first critical factor influencing the nitrogen load in the study area. A $\pm 50\%$ change in the value would lead to a change of 2977 ton N/yr in the import trade. The second factor is nitrogen leaching from agricultural soil. Modifying soil fertility by applying compost and planting grass could lead to a change of $\pm 27\%$ nitrogen emission from soil and $\pm 5\%$ N_2O decomposition into the atmosphere. Other variables such as nitrogen in crop yield and N in crop residue did not contribute to negative changes in the agriculture system

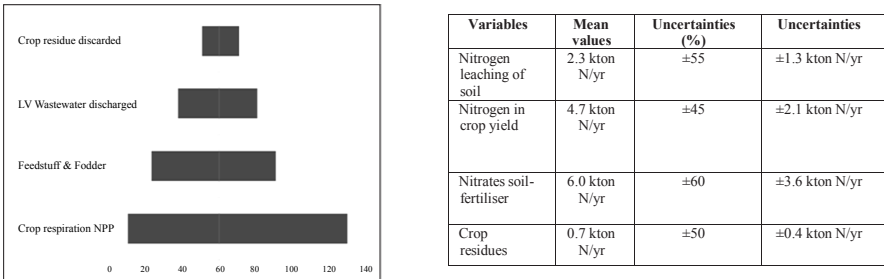


Figure 3: Limitations of the simulation results for nitrogen loads into Terengganu's agriculture system

DISCUSSION AND RECOMMENDATIONS

The regional variation estimate for nitrogen balance in the Terengganu agriculture system revealed several crucial factors and variables that might cause nitrogen loss into the environment. The application of nitrate fertilisers, crop produce, and leachate were the three key variables that influenced the nitrogen accumulation in the soil and water systems. Based on the area of land use in the seven districts, Besut and Kemaman were the areas which had the highest nitrogen accumulation

from the agriculture waste system. Each of the nitrogen loads in the agriculture system had its respective identity that was clearly influenced by the different agricultural soil management and agricultural practices.

The extent of nitrogen in the crop production system revealed that the application of nitrogen fertilisers and the disposal of crop residue were the main inputs that contributed to the nitrogen accumulation in the agricultural soil system in Terengganu. Almost 92% of the fertilisers used to increase productivity in the agriculture soil system in Terengganu, especially in intensive plantation, depended highly on non-organic fertilisers (FOA-TRG 2017). According to FAMA-TRG (2017), all nitrate-based fertilisers except urea were entirely from sources imported from outside the case system. This perpetual trend of importing raw materials is likely to cause a substantial loss in foreign exchange. Meanwhile, the nitrogen dioxide emission from fertiliser application is considered insignificant in anthropogenic global warming. However, the processes involved in intensive agriculture such as transportation, production, and the use of equipment or technologies that produce nitrogen dioxide, are considered to have an impact on ozone destruction and climate change. This is due to the fact that the potential warming effect of nitrous oxide gases (N_2O) is 300 times higher than carbon dioxide (CO_2) (Foster, 2004).

The nitrogen dioxide in crop residue disposed into the soil system in the study area also received attention, especially in the context of nutrient management practice, because it contributed an approximately 42.3% of nitrogen loss into the surrounding water body. According to interviews and records obtained at several harvesting sites (e.g. maize farm in Kuala Berang, oil palm plantation in Air Putih, Kemaman, rubber farm in Manir and paddy field in Kenak, Besut), the average production of crop residues was more than 49 kg N/ha/yr. Most of the local farmers in Terengganu removed agriculture waste from the field or burned the residue at a ratio of 0.5 to 1. Therefore, if 3 to 4 kg of nitrogen is discharged into the environment without control, 1/6 of this nitrogen would go directly into the water body because plants have a higher tendency to discharge the unused nitrogen into a water source compared to phosphate or sodium (DOE-TRG 2017). In addition, the high nitrogen concentration in the surface runoff is an important indicator of problems, especially as a proxy to evaluate eutrophication. However, it is possible for nitrogen enrichment in agricultural soil to change according to factors such as climate, morphology, nutrient ratio, climate, water resistance time, and ecosystem endurance. In the agriculture system in Terengganu, the high rainfall distribution predicts that the accumulated nitrogen concentration in soil is probably not much. However, balancing the nitrogen flow at the non-point pollution source should take priority in the study area.

Some measures to increase nitrogen efficiency in the management of the study area are as follows:

- Practice of open burning of the paddy straw and other agricultural wastes should cease. A better option would be to let those wastes

remain at ground level with a deeper ploughing into the agricultural soil.

- Expanding the planting area by planting cover crops to fortify the soil structure, thus reducing soil erosion and preventing nutrient leaching. Antikaninen *et al.* (2005) proposed bioenergy crop planting such as willow to minimise nitrogen loss through leaching from the agricultural soil. This crop could also be used as animal feed.
- Practice of a fertilising technique based on the accurate compositional needs of each crop, according to the standard stipulated by the Department of Terengganu Agriculture (DOA-TRG 2017).
- Promotion of organic farming initiatives by local authorities of Terengganu by setting fertiliser-free areas or zones, especially near to the water sources.
- Decision makers, especially from the private sector and experienced individuals should be encouraged to contribute ideas in matters related to nitrogen management in the agricultural system such as eutrophication, leaching $\text{NO}_3\text{-N}$, climate change, and so on.

For the livestock farming sector, the highest annual nitrogen surplus in TAS was contributed by variables such as animal feedstuff, animal manure and animal wastewater. Some 66% of nitrogen came from a combination of these three variables. In TAS, the harvested N consumed by farm animals in the form of straw, grasses, grains, and by-products of industrial processing was very high, up to 283 k ton of feed. Kuipers *et al.* (1999) and Tunney *et al.* (2010) proposed that the N composition in animal feed could be switched to a mixture of grasses with lower N-silage feed added with roughage such as corn. The results also show that the average reuse rate of organic fertilisers including compost from agriculture wastes as well as chicken, goat, and cattle manure was around 23–34% equivalent to 133 ton N/yr. Animal wastes including manure, bones, and ash were frequently used by local farmers to fertilise their agricultural land.

This study also verified that Terengganu agriculture region was basically free from water pollution caused by nitrogen originating from pig manure (TVSD 2018). In Malaysia, the health limit specified by WHO for nitrogen in water source should not exceed 50 mg $\text{NO}_3\text{/Liter}$. Camargo *et al.* (2005) set the nitrogen critical limit for ecological and toxicological effects related to non-organic pollution in aquatic system to be 0.5 - 1.0 mg N/Liter. The local authorities were more focused on the issues of leachate and slurry from other species such as cow, goats and poultry. The huge nitrogen loss in water was clearly occurring in the traditional free-range farming compared to the feedlot farming system in the research area. Almost 96% of the animal excreta was discharged in liquid and solid forms into the environment without first undergoing any waste treatment. According to Deng Xiang (2010), about 5 kg N/ha/yr could be converted from the pasture in the grazing system to animal products. Hence, concerted actions

including policy making, technological development, and treatment plants with aerobic and anaerobic ponds are highly needed in this region.

In general, several approaches can be adopted in nitrogen management in the livestock sector in the study area, as listed below:

- Adopting more advanced animal wastes recovery approaches
- Controlling the time and dose for fertilisation. The limit proposed by Ten Berge and van Dijk (2009) was 10%.
- Covering the animal manure stored in the farm storage to reduce volatilisation.
- Preparing a reservoir pond to hold manure slurry and leachate for at least nine months.
- Applying animal wastes during ploughing within 12 hours after land spreading.

Although the use of nitrogen in this region was balanced and under control, this is not sustainable if no follow-up measures are taken. Due to the fact that nitrate-based raw supplies for agricultural systems involves a high cost, the collaboration among the regional community, farmers' attitude, and enforcement of local regulations, is complex and requires continuous study. This study of nitrogen flow and flux in agricultural produce using SFA is useful in providing support to matters related to the calculation of influential nitrogen flow and reactive nitrogen in certain parts of the environment. This SFA study findings show that improved strategies in agricultural wastes management and efficient use of nutrients could reduce the negative impact of the nitrogen balance within the study area.

CONCLUSIONS

Using the SFA has successfully allowed us to analyse nutrient interactions in agricultural land and their impact on the environment. The excess and loss of nitrogen are the best indicators of the efficiency level of nutrient utilisation and the level of dependence on inputs and outputs of external or internal materials. Consequently, a sustainable integrated farming system can be implemented in the study area to minimise material and resource losses and environmental degradation.

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