BIOMASS FLOW IN LEAFY VEGETABLE FARM
P. Agamuthu ; L. HongYeng
Institute of Biological Sciences, Faculty Science, Faculty Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
* Corresponding author. Tel: + 603 79676756, Fax: +603 79674178, E-mail: agamuthu@um.edu.my

ABSTRACT.
Agriculture biomass waste is often the main option for waste to energy due to its large quantity and suitable waste characteristic. By turning agriculture biomass waste to energy often leads to removal of biomass from agriculture lands. However, it is a usual practice especially in Malaysia to return the biomass back to planting field to replenish the soil. Many have overlooked the benefit of biomass recycling within the farm system instead of utilizing it for energy generation. Biomass is believed to improve soil fertility and carbon sequestration by enhancing soil organic matter (SOM) content. Thus in this paper, biomass carbon flow of an organic and a conventional leafy vegetable was evaluated with material/substance flow analysis (MFA/SFA) for evidence of carbon stock. Annually there was 211 t ha\(^{-1}\) of biomass input which accounts for less than 0.09% of total farm input at organic farm (OF). While at conventional farm (CF), biomass input is only 0.08% of total farm input. The only biomass output from both farm was harvested vegetables which was 32 t ha\(^{-1}\) at OF and 1071 t ha\(^{-1}\) at CF. The substance flow shows a total of 38 tC ha\(^{-1}\) and 51 tC ha\(^{-1}\) of carbon stock within the OF and CF system and this indicates that the farm system was playing a role as carbon sink. The CF may have high C input; however, almost 96% of the total input was from photosynthesis C (crop residues). Carbon dioxide and carbon monoxide emission is one of the main culprits of carbon outflow from farm system which comprised a total of 84.67 tC ha\(^{-1}\) of carbon per year at OF and 6.79 tC ha\(^{-1}\) at CF. During the study period, the soil carbon concentration of the OF increased 70% during the study period while at CF the soil carbon concentration decreased by 5%. The C input via crop residues is crucial to soil carbon lost through agriculture activity.

Keywords: Organic and conventional, Vegetable Farm, Biomass, Material/Substance Flow Analysis, STAN

Introduction
Biomass is believed to improve soil fertility and carbon sequestration by enhancing soil organic matter (SOM) content and terrestrial ecosystem is an ideal reservoir for carbon sequestration that could offset the CO\(_2\) emission due to human activities [1]. Thus IPCC has identified biomass application in soil as the promising tool to capture and store carbon at terrestrial reservoir [2]. Crop residue, bio-solid, fertilizer, and manure are the common biomass applied at farm which contributes to soil carbon sequestration [3]. Organic farm is believed to be carbon sequester because biomass application is a common practices there. This article presents a case study of carbon flow in an organic farm and a conventional farm. The farm level analysis was chosen for three reasons. First, farm management plays a major role in carbon sequestration. Proper farm management can create carbon sink by encouraging carbon sequester practices [4]. Second, provides information about the flow and stocks of material and substances within farm system. Third, provides fundamental information for the development of farm management strategies at farm level. This analysis was conducted based on laboratory results done which present the onsite situation for this particular study. The goal of this article are to (1) identify key process and pathway, (2) determine the carbon stocks, (3) develop recommendation for goal-oriented farm management in order to ensure maximum carbon stock and minimize carbon output from the system.

Material and Methods
This study utilized the combination of field sample analysis, onsite survey and material/substance flow analysis (MFA/SFA) method to achieve objectives. Material/substance flow modeling was performed using modeling software STAN 2.5 (subSTance flow ANalysis) based on the field data collected [5].
Material/Substance Flow Analysis

Conservation theory is the basic theory of MFA/SFA where output is derived from input (also known as mass balance) and comprises the following fundamental steps [6][7][8]:

1) Determination and selection of research objective and monitoring parameters;
   This study aims to determine any relationship between amount of carbon input and carbon flux within organic farm system (OF) and conventional farm system (CF).

2) Identification of system boundaries, scope and time frame;
   The system boundary is within an organic farm (2°56’56.59”N, 101°53’25.69”E) and a conventional farm (3°25’52.66”N, 101°38’54.50”E) which located at area with an elevation of 75 meter. The selected farms are complying with Malaysia agriculture certification: Scheme Organic Malaysia (SOM) and Malaysia Good Agriculture Practices (SALM).

3) Identification of key pathways, processes, and stocks;
   Data were collected over a period of 36 months with integrated method of scientific field data collection, qualitative survey and site observation. Biomass input-output associated at the farms were identified.

4) Material flow modelling and mass balance
   Material flow modelling was performed based on the data collected from the field using STAN 2.5 (substance flow ANalysis) [5][8]. The basic theory of mass balance is that output is derived from input [6][7]. The mass change over a period of time is used to classify a process whether it is “source” or “sink” of a particular substance within a system [9].

Sample Analysis

Composite samples of soil, vegetable, compost, manure, and organic waste were sampled from the field through random sampling method and analysed at the laboratory [10][11]. Solid samples were dried at 65°C for a period of 72 hour and sieved (1mm mesh), and were analysed with Perkin Elmer CHNS/O Series II 2400 for carbon content [12]. Carbon dioxide and carbon monoxide emission was measured with 2mm acrylic static chamber (32cm x 22cm x 22cm) and portable gas detector (Binder Combimass GA-multielement) [13].

Results and Discussion

Material Flow Model

Three processes have been defined: “Farm Land” and “Vegetable Processing and Packaging”. The process Farm Land is the pre-harvest stage which involves planting activities while the process Vegetable Processing and Packaging is the post-harvest stage. The process Husbandry does not participated in farm production but was included in the model because organic waste was recycled as animal feed. Based on the biomass input and output identified a biomass balance was established. Figure 1 shows the compost (2,757 ton ha⁻¹ y⁻¹) and Bokashi compost (276 ton ha⁻¹ y⁻¹) were the major biomass input in the farm system while harvested vegetable (112 ton ha⁻¹ y⁻¹) was the main biomass output. The MFA model shows that the farm recycled organic wastes generated from the post-harvest processing as animal feed (6.15 ton ha⁻¹ y⁻¹).

Carbon Flow Analysis

The STAN model shows the biomass input has contributed to 41 t ha⁻¹ y⁻¹ and 163 t ha⁻¹ y⁻¹ of total carbon into the OF and CF system, respectively. The higher C input at CF was main contributed by photosynthesis carbon (crop residues). Generally the biomass input of OF is higher compared to CF if photosynthesis carbon is excluded from model. This highlight the important of crop residue in carbon flux especially for farm that have lower biomass input like CF in this study. Vegetable production is the only biomass output from the farm system and crop residues often left on the farm as nutrient replenishment. Therefore, total C derived from photosynthesis is included into the SFA model. Each year around 38 tC ha⁻¹ y⁻¹ and 51 tC ha⁻¹ y⁻¹ (dstock) of carbon has stocked into the OF and CF system. This indicates the farms have the potential to be carbon sequester due to high input biomass. This result agrees with the carbon flux modelling by Vleeshouwers and Verhagen (2002) where the usage of organic matter input
increases carbon in carbon flux[14]. The soil carbon concentration during the study period was measured and the results shows there is an increment of 70% at OF and the soil carbon concentration at CF decrease for 5%. The variation may be due to C input at CF was loss via runoff and leaching.

Fig.1. Biomass flow analysis for organic farm, 2012-2014

Fig.2. Biomass flow analysis for conventional farm, 2012-2014

There are reports questioning the benefit of carbon input in carbon sequestration. This is because the carbon input increases soil carbon but in the same time encourages microbial decomposition activity which leads to higher carbon emission [15]. The carbon gaseous emissions were measured and the results show OF release higher rate of CO₂ and CO than CF. A total of 84.67 tC ha⁻¹ y⁻¹ at OF and 6.79 tC ha⁻¹ y⁻¹ at CF were lost via C gaseous emission. The higher C lost via gaseous emission at OF may due to higher microbial activity.
Fig. 3. Biomass C flow analysis for organic farm, 2012-2014

Fig. 4. Biomass C flow analysis for conventional farm, 2012-2014
Conclusions
The carbon flow model in this study implies that the both organic and conventional farm has the potential to be carbon sink even when carbon emissions were taken into account for the carbon flow analysis. The C input via crop residues is crucial to offset the soil carbon lost through agriculture harvesting.

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References

