

**INTEGRATION OF MFA, LCA AND GIS AS  
A SIMULATION DECISION SUPPORT  
TOOL FOR BIOMASS AGRICULTURE  
WASTE MANAGEMENT IN TERENGGANU  
STATE**

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**DOCTOR OF PHILOSOPHY  
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SIMULATION DECISION SUPPORT TOOL FOR  
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**LATIFAH ABDUL GHANI**

**Thesis Submitted in Fulfillment of the  
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“In the name of Allah S.W.T. That the Most Gracious, and the Most Merciful”

This thesis is dedicated to

My Husband (Mohd Khairul Amri bin Yahya)

My beloved mother (Rasidah Bt Haji Mohamed Taib)

My advisor (Prof Noor Zalina Mahmood & Prof Nora'aini Ali)

My daughter (Zulaikha bt Mohd Khairul Amri)

My family (Haryati, Hazwani, Nur Karimah, Umi Salmah, Siti Muliani)

And

Thank you very much to those who had given me their helping hand all  
the way during my research program that I did not mention above

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**LATIFAH BINTI ABDUL GHANI**

**October 2015**

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**Faculty : School of Ocean Engineering**

The worsening depletion of nature reserves and the deterioration of environment make the integration of several environmental assessment tools increasingly important and more relevant to be further developed. Terengganu is one of the states in Malaysia with high amount of biomass contents from agricultural wastes that are currently not used as useful resources. Therefore, this study was conducted to evaluate the biomass flow balance from the agricultural wastes in an integrated framework using a combination of Geographic Information System (GIS) and Life Cycle Assessment (LCA) into Material Flow Analysis (MFA) technique. Three parameters were selected to be analysed in the agriculture system of Terengganu, namely Agriculture waste (AgW), Nitrogen (N) and Biomass Energy (BE). The findings were analysed using STAN, GaBi, SimaPro, and ArcGIS software. The

MFA findings successfully identified the material flow, mass allocation, and arising issues in agricultural wastes in the study site. The findings also successfully identified that the amount of biomass availability from the agricultural wastes was very high, namely 1011 kton AgW/yr. The flow balance of agricultural wastes in Terengganu's agriculture metabolism was found to be in an intermediate range with its overall input and output values of 453 kton AgW/yr and 505 kton AgW/yr, respectively. The MFA findings were integrated into GIS (MAGI) to show the visualisation view of input, output, and material stock maps from spatial-temporal effect dimension. The study result revealed the availability density of biomass energy sources in Kuala Nerus and Belara areas. Besides, the highest nitrogen accumulation in agriculture land system was recorded in Kemaman and Setiu districts. After obtaining the visualisation result, this study focused on the impacts of agricultural wastes management practice in four scenarios namely S1: On-farm burial, S2: On-farm burning, S3: Landfill, and S4: Recycled. The result analysis combined MFA and Life Cycle Assessment (LCA) (MALA) and recorded that S1 and S3 to be showing a credit value while S2 and S4 to be showing a debit value for environmental damage. However, overall, the potential range of environmental damage in the study site was still in a safe zone. As a result, the integration of Material Flow Analysis (MFA) with Geographic Information System (GIS) and Life Cycle Assessment (LCA) (MAGILA) was arranged in the best methodology to produce the following chronology: source, location, and impacts. Finally, the success of MAGILA framework development in this thesis can be applied in other agricultural regions, at local, national, or global levels, after some modifications.

Abstrak tesis ini dikemukakan kepada senat Universiti Malaysia Terengganu sebagai memenuhi keperluan untuk Doktor Falsafah

**INTEGRASI MFA, LCA AND GIS SEBAGAI SIMULASI ALAT  
SOKONGAN KEPUTUSAN UNTUK PENGURUSAN BIOJISIM SISA  
PERTANIAN DI NEGERI TERENGGANU**

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Pengurangan rizab alam dan kemerosotan alam sekitar yang semakin meruncing menjadikan keperluan integrasi beberapa alat penilaian alam sekitar semakin penting dan relevan untuk diperkembangkan. Terengganu, iaitu salah satu negeri di Malaysia yang mempunyai kandungan biojisim daripada sisa buangan pertanian yang tinggi dan tidak digunakan sebagai sumber yang berguna pada ketika ini. Oleh itu, kajian ini dijalankan untuk menilai keseimbangan aliran biojisim daripada sisa buangan pertanian dalam satu sistem rangka kerja bersepadu menggunakan kaedah gabungan Sistem Maklumat Geografi (GIS) dan Penilaian Kitar Hayat (LCA) kepada teknik Analisis Aliran Bahan (MFA). Tiga parameter dipilih untuk dianalisis dalam sistem pertanian di Negeri Terengganu adalah sisa pertanian (AgW), Nitrogen (N) dan Tenaga Biojisim (BE). Data-data kajian dianalisis menggunakan perisian STAN,

GaBi, SimaPro dan ArcGIS. Dapatan kajian Analisis Aliran Bahan (MFA) telah berjaya mengenalpasti aliran bahan, alokasi jisim dan masalah yang timbul dalam pengurusan sisa buangan pertanian di kawasan kajian. Hasil kajian telah mengenalpasti jumlah ketersediaan biojisim daripada buangan pertanian adalah sangat tinggi iaitu 1011 kton AgW/yr. Keseimbangan aliran sisa buangan pertanian dalam metabolisma pertanian Terengganu pula berada dalam julat sederhana dengan nilai keseluruhan input dan output masing-masing adalah 453 kton AgW /yr dan 505 kton AgW/yr. Hasil dapatan Analisis Aliran Bahan (MFA) ini diintegrasikan bersama dengan Sistem Maklumat Geografi (GIS) (MAGI) untuk memberikan paparan visualisasi peta-peta input, output dan stok bahan daripada dimensi kesan ruang-masa. Keputusan kajian menunjukkan densiti ketersediaan sumber tenaga biojisim di mukim Kuala Nerus dan Belara. Manakala, pengumpulan nitrogen di dalam sistem tanah pertanian yang tertinggi direkodkan di daerah Kemaman dan Setiu. Selepas keputusan visualisasi diperolehi, kajian ini memfokus kepada impak amalan pengurusan sisa buangan pertanian dalam empat senario iaitu S1: di tapak tuaian, S2: pembakaran di ladang, S3: Tapak perlupusan dan S4: Kitar semula. Hasil analisis menggabungkan Analisis Aliran Bahan (MFA) dan Penilaian Kitar Hayat (LCA) (MALA) telah merekodkan S1 dan S3 menghasilkan nilai kredit untuk kemusnahan alam sekitar berbanding nilai debit, masing-masing untuk S2 dan S4. Namun, secara keseluruhan julat potensi kemusnahan alam sekitar di kawasan kajian masih lagi berada di zon yang selamat. Analisis Aliran Bahan (MFA) dengan Sistem Maklumat Geografi (GIS) dan Penilaian Kitar Hayat (LCA) (MAGILA) telah disusun dalam metodologi yang terbaik bagi menghasilkan kronologi berikut; sumber, lokasi dan impak. Akhir sekali, keberhasilan pembangunan rangka kerja

MAGILA dalam tesis ini boleh diaplikasi kepada wilayah pertanian yang lain di peringkat tempatan, nasional atau global setelah diberi pengubahsuaian dalam beberapa perkara.