

## Tractor with Built-in DGPS for Mapping Power and Energy Demand of Agricultural Field Operations in Malaysia

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### Introduction

Great deal of attention has been focused on reducing chemical and fertilizer costs and increasing crop yield while ignoring the fact that there are other inputs contributing to the total production costs. Tractors have been the prime power unit for land preparation, field maintenances and transportation in the paddy production industry in Malaysia. Majority of the farmers contracted out most of the tractor field operations due to the high initial and maintenance costs of tractors-implement. The farmers had their tractor field operations done by the contractors without realizing the quality of work they received for the given service. On the other hand, the contractors gave the services to the farmers without realizing that the tractor-implement combinations they used were not properly set-up. Thus, significant profit improvements would be possible in the paddy production if the machinery resources were utilized more efficiently in completing the field operations. This study involved with the development and integration of a complete data acquisition and DGPS system on an agricultural tractor for mapping of terrain trafficability, tractor-implement performance, and tillage quality.

### Materials and Methods

The platform of this research is a Massey Ferguson 3060, agricultural tractor with a rated engine power of 64 kW@2200 rpm. The tractor is equipped with a 4.07 L, naturally aspirated, direct injection, 4 cylinders PERKINS engine and selectable 2 or 4 wheel drive options. The tractor manufacturer had earlier installed some basic instrumentation on-board and further extensive work was carried out on the available system for the purpose of having more complete information on power and energy demand of field operations in Malaysia (Kheiralla and Yahya, 2001). Apparently, the newly developed data acquisition and DGPS system on-board the tractor together with the automated soil penetrometer-shearometer unit, built-in transducers on the tractor, and automated soil surface profile digitizer were capable of providing information on terrain trafficability, tractor-implement performance, and tillage quality with respect to the tractor's geo-position. Spatial variability information could be extracted from the generated maps to assist managers in the decision process of optimizing the field operations.

### Results and Discussion

A tractor-implement performance system had been designed and developed for measuring tractor-implement performance while working in the field on-board a Massey Ferguson 3060 agricultural tractor. The data acquisition system is interfaced with both factor installed and newly developed transducers. The developed transducers involves drawbar pull at the tractor drawbar point, wheel torques at both tractor rear drive wheels, PTO torque at the tractor PTO output, three-point auto hitch at the tractor three-point linkages and theoretical speed at tractor both ends final drive. The data acquisition system is also interfaced to differential global position system for precision farming applications. The developed system was capable to measure, display and record in real-time among other, the tractor's theoretical speed, actual speed, fuel consumption rate, drive wheel slippage, drive wheel torque, and implement's PTO shaft torque, drawbar force, and three-point hitch forces. Optional was also provided to the system to identify, display and record in real-time the geo-position of the tractor-implement in the field with the respect to its measured performance.

A mounted type automated soil penetrometer-shearometer unit had been designed and developed for the Massey Ferguson 3060 agricultural tractor to measure soil mechanical parameters for quantifying terrain trafficability. The unit makes use of the commercial penetrometer and shearometer instruments. These two instruments were housed in a special made frame having gear driving mechanisms and a three-point hitch attachment. The motion controls for the unit were performed by PLC and other external electronics and sensing devices. Two stepper motors were used to drive the penetrometer and shearometer moving carriages in the vertical axis direction while another stepper motor was used to drive the rotating spindle of the shearometer. The complete unit was capable of measuring the soil penetration resistance and shear stress in the range of 0 to 10 MPa and of 500 to 600 kg/cm, respectively.

A towed type automated 3-axis laser soil surface profile digitizer had been designed and developed for the Massey Ferguson 3060 agricultural tractor to measure soil surface profile for quantifying the soil tilth degree. The measurement system utilized laser displacement sensor and housed in special design trailer. The motion control for the digitizer was performed by PLC and together with other external electronics and sensing devices. Three stepper motors were used to drive the laser displacement sensor in the 3-axis digitizing directions. The system was able to digitize an area of 1.2m x 1.8m with provisions of varying the digitizing interval to the required operation time and resolution.

### Conclusions

A novel data acquisition and DGPS system had been developed and integrated on-board an agricultural tractor with both commercially and special made sensors, a mounted type automated soil penetrometer-shearometer unit, and a towed type automated 3-axis laser soil surface profile for mapping of terrain trafficability, tractor-implement performance, and tillage quality with geographical location during field operations. The complete system was capable of measuring, displaying, and recording in-real time the tractor's position, soil penetration resistance and soil shear stress when mapping terrain trafficability; the tractor's position, engine speed, travel speed, fuel consumption, drive wheel slippage, drive wheel torque, PTO shaft torque, drawbar force, and three-point hitch forces when mapping tractor-implement performance; and the tractor's position, soil surface profile, and soil tilt index when mapping tillage quality.

### Benefits from the study

The project output is a new contribution on specialized mobile instrumentation having the state-of-the-art technology that has enormous potentials for precision farming applications on managing the site-specific-variability of terrain trafficability, tractor-implement field performances and tillage quality, developing comprehensive information database on soil information, power and energy demand of various tractor field operations, and field testing and evaluation of any new agricultural implements.

### Patent(s), if applicable

1. 3-Axis Automated Soil Profile Meter, 2. Soil Cone Index and Shear Strength Mapper, 3. Tractor-implement Performance Mapping System, 4. 3-point Auto Hitch Tractor Dynamometer

**Stage of Commercialization, if applicable:** Not yet

### Project Publications in Refereed Journals

1. Azmi Yahya, M. Zohadie, A. F. Kheiralla and G. S. Kiat. 2003. FILTRAP system for testing and evaluation tractor-implement field performance. *ASEAN journal on Science & Technology for development* (submitted)
2. Azmi Yahya, M. Zohadie, A. F. Kheiralla and G. S. Kiat. 2003. Field Performance Testing and Evaluation Facility for Ride-on Agricultural Tractor-Implement at UPM. *The Planter* (submitted)
3. Kheiralla, A. F. and Azmi Yahya. 2003. Design, development and calibration of a drive wheel torque transducer. *Pertanika J. Sci.&Technol* 11(2): (in press).
4. Kheiralla, A. F., Azmi Yahya, Mohd Zohadie Bardaie and Wan Ishak Wan Ismail. 2003. Design and development of a three-point auto hitch dynamometer for agricultural tractor. *ASEAN journal on Science & Technology for development* (in press)
5. Kheiralla, A. F., Azmi Yahya, Mohd Zohadie Bardaie and Wan Ishak Wan Ismail. 2003. Power and energy requirement modeling 1: draught implements operating in Serdang sandy clay loam, Malaysia. *ASEAN journal on Science & Technology for development* (in press)
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7. Kheiralla, A. F., Azmi Yahya, Mohd Zohadie Bardaie and Wan Ishak Wan Ismail. 2002. Power and energy requirement modeling of tillage implements operating in Serdang sandy clay loam, Malaysia. *Soil and Tillage Research* (revised).
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9. Kheiralla, A. F. and Azmi Yahya. 2001. A tractor data acquisition system for power and energy demand monitoring of agricultural field operations. *Pertanika J. Sci.&Technol*. 9(1): 51-67.
10. Kheiralla, A. F. and Azmi Yahya. 2001. Design, development and calibration of a drawbar pull transducer for agricultural tractor. *Pertanika J. Sci.&Technol*. 9(1): 81-98.

### Project Publications in Conference Proceedings

1. Ng Eng Boon, Azmi Yahya, A. F. Kheiralla, Wee Beng Sui, and Gew Soon Kiat. 2003. automated soil penetrometer-shearometer unit for measuring soil penetration resistance and shear stress. *Proceedings of Advanced Technology Congress*, May 20-21, 2003, Putrajaya, Malaysia.
2. Wee Beng Sui., Azmi Yahya, Isa Osman, Bambang Suparjo Sunarjo. A. F. Kheiralla, and Ng Eng Boon. 2003. 3D Mapping of soil surface profile with an automated, mobile-type, 2-axis laser digitizer. *Proceedings of Advanced Technology Congress*, May 20-21, 2003, Putrajaya, Malaysia.

3. Azmi Yahya, M. Zohadie, A. F. Kheiralla, S. K. Gew, B. S. Wee, and E. B. Ng. 2002. A Tractor with Built-in Data Acquisition and Differential Global Positioning System for Mapping Terrain Trafficability, Tractor-Implement Performance, and Tillage Quality. *Seminar on application of remote sensing, GIS and related technologies for precision farming: Precision farming technologies for sustainable agriculture*. 9<sup>th</sup>–11<sup>th</sup> September, Kuala Lumpur 16 pp.
4. Kheiralla, A. F. and Azmi Yahya. 2002. Design, development and calibration of a Three-point Auto Hitch Dynamometer for agricultural tractor. *Biological, agricultural and food engineering: Proceedings of 2<sup>nd</sup> World Engineering Congress (WEC2002), Engineering innovation and sustainability: Global challenges and issues*, 22<sup>nd</sup>- 25<sup>th</sup> July 2002, Kuching, Sarawak, pp 293-300.
5. Kheiralla, A. F., Azmi Yahya and Tan Lee. 2002. Design, development and calibration of a Tractor PTO Shaft Torque Transducer. *Biological, agricultural and food engineering: Proceedings of 2<sup>nd</sup> World Engineering Congress (WEC2002), Engineering innovation and sustainability: Global challenges and issues*, 22<sup>nd</sup> 25<sup>th</sup> July 2002, Kuching, Sarawak, pp 327-333.
6. Kheiralla, A. F., Azmi Yahya, Mohd Zohadie Bar daie and Wan Ishak Wan Ismail. 2002. Modeling of Power and Energy Requirement of Postive Draft Implement in Malaysia. *Biological, agricultural and food engineering: Proceedings of 2<sup>nd</sup> World Engineering Congress (WEC2002), Engineering innovation and sustainability: Global challenges and issues*, 22<sup>nd</sup> 25<sup>th</sup> July 2002, Kuching, Sarawak, pp 301-310.
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11. Kheiralla, A. F. and Azmi Yahya. 1999. Design, development and calibration of a drawbar pull transducer for agricultural tractor. *Proceedings of 1<sup>st</sup> World Engineering Eongress (WEC1999), towards the engineering vision: global challenges and issues*. Kuala Lumpur, pp 1-5,
12. Kheiralla, A. F. and Azmi Yahya. 1999. Design, development and calibration of a drive wheel torque transducer. *Proceedings of Malaysian science and technology congress '1999*. Symposium A, Volume I. COSTAM October 25-27, 1999. Ming Court, Kuala Lumpur. 6 pp.

#### Graduate Research

Name Graduate	of Research Topic	Field of Expertise	Degree Awarded	Graduation Year
Abdelmotalab Fadlemola Kheiralla	Tractor with Built-in Instrumentation System	Precision Farming	Ph.D	2002
Wee Beng Shui	Mobile 2 Axis Laser Soil Surface Profile Meter	Agricultural Automation and Robotics	M.S	2003 (submitted)
Gew Soon Kiat	Mapping Tractor Field Performances	Bioproduction Machinery	M.S	2003 (submitted)
Ng Eng Boon	Automated Soil Penetrometer and Shearometer Unit	Agricultural Automation and Robotics	M.S	

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