UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF MACHINERY OPERATIONS AND QUALITY FIELD PRACTICES ASSESSMENT FOR WETLAND RICE CULTIVATION AREA IN MALAYSIA

MODATHER MAIRGHANY ABDIN AHMED

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By

MODATHER MAIRGHANY ABDIN AHMED

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

Dedicated to

My Parents,

My Brothers & sisters,

My Wife,

My Friends, and to

My Lovely kids:

Lamees,

Mohamed,

Monzer,

Layar,

Lareen

.....With Love……

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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MODATHER MAIRGHANY ABDIN

November 2020

Chairman : Professor Azmi bin Dato' Yahya, PhD, P.Eng.
Faculty : Engineering

Rice is one of the most essential staple foods for a large part of the world's population including Malaysia, and there is a need to increase production for filling the gap between production and consumption. Maximum paddy productivity could be achieved through the implementation of the best and most effective agricultural practices and the maximum quality of operations output. The Rice Check system is a holistic integrated crop management component that provides objective recommendations and a method of use to improve the yields, grain quality, and profitability of rice growing. In this study, *in situ* comprehensive evaluation of farm operations and practices conducted in 30 farms for two seasons at Sungai Burong, North-West Integrated Agricultural Development Authority Selangor Malaysia was conducted. The study aims to evaluate the quality of agricultural practices and machinery operations based on the Rice Check and determine the most effective key parameter for improving the quantity production, then optimize the effective input by using an optimization model. To evaluate practices and operations quality, six benchmarking parameters were selected, namely (1) seeding, (2) tillage, (3) water management, (4) fertilization, (5) chemical spraying, and (6) harvesting. A comprehensive evaluation of the quality and effectiveness of all agricultural operations and practices was performed to assess the degree of perfection and quality index of these farming practices, agricultural operations, and the effect of that on the crop in general and the yield as final output was performed. The evaluation was done based on four rights, right source, the right amount, right timing, and right placing and quality of these operations. Multiple linear regression was used to rank the parameters of the cultural practices based on the most effective yielding and the key parameter subjected to the DEA optimization model for high-yielding rice. The result showed that for land preparation just 22.6% of farmers follow exactly the requirement of the Rice Check, for tillage practices 61.9% of farmers follow, for planting 26.2% of farmers follow, for pesticides 44.4% of farmers follow, for fertilizer, 41.1% of farmers follow, and for harvesting, 37.5% of farmers follow the Rice check recommendations. Farmers do not follow the standard in terms of amount, source, and timing of operations in total. In terms

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of operation quality, tillage is ranked as first achieving 100% of the quality index, and pesticide operation the lowest-achieving 56.4%. Fertilizer has 78.7% Q.I, (quality index), planting achieved 86.7%, harvesting 78.7%, and water irrigation 62.4%. For ranking the parameters, multiple linear regression showed that fertilizer is the most effective parameter on rice yield/production with $R^2 = 0.85$, then planting with $R^2 = 0.80$ followed by pesticides $R^2 = 0.52$. Fertilizer and pesticide inputs were subjected to data envelopment analysis optimization models by using the GAMS optimization package. Running the models showed there were just 5 (16.7%) efficient plots for CCR-I and CCR-O, just 7 (23.3%) efficient plots for BCC-I, and 8 (26.7%) efficient plots for the BCC-O model. Results showed that there was excess use of input materials more than the required optimum ranges from 13.3% (18.1 kg/ha) for Nitrogen, 12% (10.9 kg/ha) for Phosphorus 17.1% (11.4 kg/ha) for Potassium, Fungicides 32.6%, Liquid Insecticides 34.2%. Powder Insecticide 39.0%, and Herbicides 28.9%. It could be concluded that the quality indices for agricultural practices and operations were (61.9 and 100%) for tillage, (26.2 and 86.73%), for planting, (37.7 and 56.4%) for pesticides, (41.4 and 78.71%) for fertilizer, and (37.5 and 78.7%) for harvesting respectively, for water management the quality index was 67.1%. The most effective parameter on yield of rice was the fertilizer, 2nd was the planting, 3rd was the pesticides, 4th was the harvesting, and 5th was the soil factor.

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PEMBANGUNAN OPERASI JENTERA DAN PENAKSIRAN KUALITI AMALAN LADANG UNTUK PENANAMAN PADI BASAH DI MALAYSIA

Oleh

MODATHER MAIRGHANY ABDIN

November 2020

Pengerusi: Profesor Azmi bin Dato' Yahya, PhD, P.Eng.
Fakulti: Kejuruteraan

Nasi adalah salah satu makanan asas yang paling penting untuk sebahagian besar populasi dunia termasuk Malaysia, dan wujud keperluan meningkatkan pengeluaran untuk mengisi jurang antara pengeluaran dan penggunaan. Produktiviti padi maksimum dapat dicapai melalui pelaksanaan amalan pertanian terbaik dan berkesan dan kualiti operasi maksimum. Sistem Jadual Semak Padi (Rice Check) adalah komponen pengurusan tanaman bersepadu holistik yang memberikan cadangan objektif dan kaedah penggunaan untuk meningkatkan hasil, kualiti biji-bijian, dan keuntungan penanaman padi. Dalam kajian ini, penilaian *in situ* menyeluruh untuk operasi lading dan amalan ladang yang dilakukan di 30 ladang selama dua musim di Sungai Burong, dibawah Lembaga Pembangunan Pertanian Bersepadu Utara-Barat Selangor Malaysia. Kajian ini bertujuan untuk menilai kualiti amalan pertanian dan operasi mesin berdasarkan Sistem Semak Padi (Rice Check) dan menentukan parameter utama yang paling berkesan untuk meningkatkan kuantiti pengeluaran, kemudian meminimumkan input berkesan dengan menggunakan model DEA dengan menetapkan kuantiti pengeluaran dan memaksimumkan kuantiti pengeluaran pada input berkesan yang ditetapkan (fixed). Untuk menilai amalan dan kualiti operasi, sebanyak enam parameter penanda aras, telah dipilih yaitu (1) penyemaian, (2) pembajakan (3) pengurusan air, (4) pembajaan, (5) penyemburan kimia, dan (6) penuaian. Penilaian dilakukan berdasarkan empat hak, ia itu sumber yang tepat, jumlah yang tepat, waktu yang tepat, dan penempatan yang tepat dan kualiti semua operasi ini. Regresi berbilang linear telah digunakan untuk menentukan pepangkatan parameter amalan pertanian berdasarkan hasil yang paling efektif dan parameter utama yang melalui aplikasi model pengoptimuman DEA untuk beras hasil tinggi. Penilaian komprehensif mengenai kualiti dan keberkesanan kesemua operasi dan amalan pertanian yang dilakukan untuk menilai tahap kesempurnaan dan indeks kualiti amalan pertanian, operasi pertanian, dan kesannya terhadap tanaman secara umum dan hasil pertanian sebagai hasil akhir. Keputusan menunjukkan bahawa untuk penyediaan tanah hanya 22.6% petani mengikuti syarat dengan tepat keperluan Sistem Semak Padi, untuk amalan pembajakan 61.9% petani mengikuti,jadual yang disyorkan, manakala untuk penanaman 26.2% petani mengikuti jadual Semak, untuk racun perosak, 44.4% petani mengikuti, Jadual Semak; untuk pembajaan 41.1 % petani

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mengikuti, Jadual Semak dan untuk penuaian, 37.5% petani mengikuti cadangan Semak Padi. Petani tidak mengikut standard dari segi jumlah, sumber, dan ketepatan waktu operasi. Dari segi kualiti operasi, pembajakan tanah diperingkat pertama mencapai 100% indeks kualiti, dan operasi racun perosak adalah terendah yakni mencapai 56.4%. Pembajaan mempunyai 78.7% Q.I, penanaman mencapai 86.7%, penuaian 78.7%, dan pengairan 62.4%. Untuk parameter pemangkatan, regressi berbilang linear menunjukkan bahawa pembajaan adalah parameter yang paling efektif terhadap hasil / pengeluaran padi dengan $R^2 = 0.85$, diikuti penanaman $R^2 = 0.80$ dan penyemburan racun perosak $R^2 = 0.52$. Input baja dan racun perosak diaplikasikan model pengoptimuman analisis envelopment data dengan menggunakan pakej pengoptimuman GAMS. Penggunaan model menunjukkan hanya terdapat 5 (16.7%) petak cekap untuk CCR-I dan CCR-O, dan hanya 7 (23.3%) petak yang cekap untuk BCC-I, dan 8 (26.7%) petak yang cekap untuk BCC-O model. Hasil kajian menunjukkan bahawa sekitar 13.3% (18.1 kg / ha) dari jumlah input baja digunakan lebih banyak daripada nilai yang optimum yang diperlukan. Lebihan penggunaan bahan input antara 13.3% (18.1 kg / ha) untuk Nitrogen, 12% (10.9 kg / ha) untuk Fosfor 17.1% (11.4 kg / ha) untuk Kalium, Racun kulat 32.6%, Racun Perosak Cecair 34.2%. racun serangga serbuk 39.0%, dan Herbisida 28.9%. Dapat disimpulkan bahawa indeks kualiti untuk praktik dan operasi pertanian adalah (61.9 dan 100%) untuk penanaman, (26.2 dan 86.73%), untuk penanaman, (37.7 dan 56.4%) untuk racun perosak, (41.4 dan 78.71%) untuk baja , dan (37.5 dan 78.7%) untuk penuaian masing-masing, untuk pengurusan air indeks kualiti adalah 67.1%. Parameter yang paling berkesan terhadap hasil padi adalah baja, ke-2 adalah penanaman, ke-3 adalah racun perosak, ke-4 adalah penuaian, dan ke-5 adalah faktor tanah. Baja dan racun perosak dioptimumkan menggunakan model DEA, jumlah optimum dan akses ditunjukkan.

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Azmi bin Dato Yahya, PhD, P.Eng.
Professor, Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Nor Mariah binti Adam, PhD, P.Eng.
Professor, Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Ahmad Suhaizi bin Mat Su, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 14 October 2021

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted, and the writing of this thesis was under our supervision;
- Supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

Signature: _____
Name of
Chairman of
Supervisory
Committee: Professor Ir. Dr. Azmi bin Dato Yahya

Signature: _____
Name of
Member of
Supervisory
Committee: Professor Ir. Dr. Nor Mariah binti Adam

Signature: _____
Name of
Member of
Supervisory
Committee: Dr. Ahmad Suhaizi bin Mat Su

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LIST OF ABBREVIATIONS

M_d	Mass of dry soil sample (grams).
BCC-I	Banker, Charnes and Copper, Input Oriented
BCC-O	Banker, Charnes and Copper, Output Oriented
BDS	Broadcasted Direct Seeding
CCR-I	Charnes, Cooper and Rhodes, Input Oriented
CCR-O	Charnes, Cooper and Rhodes, Output Oriented
DAP	Days After Planting
DAT	Days After Transplanting
DEA	Data Envelopment Analysis
DMU	Decision-Making Unit
D_b	Bulk Density g/cm^3
D_p	Soil particle Density g/cm^3
GMC	Gravimetric Water Content
MC	Moisture Content
MOG	Material Other Than Grain
MTP	Mechanic Transplanting
PR	Penetration Resistance MPa
SPR	Soil Penetration Resistance MPa
TE	Technical Efficiency
PTE	Pure Technical Efficiency
V	Soil Volume
VMC	Volumetric water content
ϕ	Total porosity

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

One of the great challenges that face people in the world every day is how to feed the greatest growth of the global population which is rising uncontrollably and expected to increase to nine billion by the year 2050 (FAOSTAT 2018). While the availability of agricultural arable land is declining year after year due to the huge increase of urbanization, and the soil problems caused by flooding, drought, and increasing salinity levels. Also, weather conditions and climate changes could affect the harvested yield in both quality and quantity. Nowadays, agriculture is considered as very low income and discourages the sector for people to work in, and this also affects food production. Rice is one of the most essential staple foods for a large part of the world's human population as well as Malaysia. The country depends on imported rice to meet the shortage of domestic productions against demands. Increasing production and enhancing paddy productivity could be achieved through the implementation of the best and most effective agricultural practices and the quality of output of farming practices and operations.

To realize world food sufficient based on agricultural food production, agricultural practices, and machinery operations must be managed in a quality manner to achieve high output within the same input used and minimize both the losses and miss placing inputs of the crop in the field. These farming quality management systems should be involved in all rice production stages. Firstly, land preparation and physical properties of the soil should be managed and controlled to be the base of increasing rice production by creating a suitable proportion between the three main factors of solid, water, and gaseous (Gliński and Lipiec., 1990) and availability of adequate porosity that allows the plant to uptake the adequate needed of water, mineral, and fertility. Soil physical properties are considered a vital role in plant growth. No doubt that tillage influences and affects the soil's physical properties. The first step to guaranteeing that the crop can achieve the highest potential yield is land preparation in a way ensuring that the crops found the optimum conditions and uptake an adequate amount of needed material for the necessary development. Rice fields should be ready for planting at the right time. Tillage is the main tool used for land preparation and soil physical properties controlling and management, if it is used properly could be an important means to prepare the land in the direction of achieving the potential utility and productivity. On the other hand, tillage could have a negative impact if it does not use properly causing soil degradation accelerated erosion, declination of soil fertility and organic matter, and so on. Proper tillage prepares land perfectly, controls weeds, recycles and distributes plant nutrients, and softens the mass of soil to facilitate the working of mechanical transplanting. One of the important factors of preparing land is leveling the field as it improves the efficiency of water using, shares in yield increasing, and improves the quality of grain as it ensures uniform and adequate water availability for the plant. Many researchers showed that the increase of soil strength decreased the yield, it could be measured by the determination of soil penetration resistance. Tillage affects soil physical properties such as soil bulk

density, penetration resistance, and soil porosity. As reported by (Hillel, 1982) when the soil contains 50% solid particles and 50% pore space volume it considers ideal soil. The level of bulk density commonly ranges from 0.9 to 1.8g/cm^3 (Erbach, 1987). Husnjak et al. (2002) reported that there is a strong reciprocal dependence between bulk density and crop yield, while there is a strong direct dependence between porosity and crop yield.

The second step in achieving high production and productivity is the quality of planting to establish the plant in a perfect condition that allows the crop to grow healthy and in proper spacing with an optimum density with the least seeding and planting losses. Rice plants by two main methods direct seeding and transplanting, every one of them has many types and many machines used for that purpose. The transplanting technique is used widely in most countries in Asia, as rice is normally grown by transplanting the young seedlings into a wet puddled soil where the land is prepared by performing tillage or puddling in a flooded or saturated soil (Kumar and Ladha, 2011). Both of these methods of direct seeding and transplanting have advantages and disadvantages. However, in the transplanting method weed is efficiently managed better than indirect seeding which always gave a higher yield than direct seeding (Ehsanullah et al., 2007). Looking towards the labor shortage in the farm manual transplanting operations in some countries, governments promote mechanized transplanting to make farming more profitable. The farmers have come forward to adopt transplanting with the help of a self-propelled rice transplanting machine. Due to small landholding and farmers' weak economic position, they are not in a position to purchase the machine individually, but on a hiring basis, the technology should be adopted (Guru et al., 2018). The uneven field surface is the main factor influencing the performance of paddy mechanical transplanting, well puddled and leveled field is crucial with no standing water on the soil surface as it creates more floating hills. Before transplanting operation, the fields were puddled uniformly and left for 24 hours to allow the puddled soil to settle down completely and to avoid soil flow to ensure better seedling establishment. Mechanical self-propelled rice transplanting machine has many problems with wet puddled soil in wetland cultivation areas as same as other agricultural machinery. Poor traction, sinkage, and steerability are the main problems of the transplanting machine. This problem could be avoided if the field was prepared properly and did not loosen more than the soil required level, the soil should have sufficient bearing capacity to hold the machine without sinking (Behera, 2009).

The farmers tend to soften and loosen the topsoil too much which leads to these problems to the mechanical transplanting machine. Farmers do not follow Rice Check recommendation in drainage the field before the harvesting operation this makes it impossible to drain the field after harvesting due to the huge grooves made by the harvester, this leads to submerge the soil with water for a long time and delay the first plowing, and that leads to softening and loosening the soil more than the required. Transplanted rice showed a significant effect as compared to direct-seeded rice in plant growth characters like plant height and plant population/m^2. At harvest, transplanted crop recorded significant effect in all growth characters as compared to direct-seeded which might be due to optimum spacing between every two rows and the distance between a plant that resulted in less competition between the plants, higher nutrient uptake due to even planting distribution and lesser weed infestation, light interception and so, all the characters such as plant height, plant population/m^2 were more in transplanting condition

than direct seeding (Konwar et al., 2018). To gain satisfied crop yield, there should plant a suitable amount of seed in a suitable prepared area uniformly.

The third step of improving crop productivity and increasing production and crop yield is improved water efficiency, and by controlling and managing irrigation systems, and the drainage system which is crucial to achieving a full potential yield of rice. Produce optimum rice yields through continuous flowing flooding irrigation, with 10 to 15 cm depth of water and that is perfect to achieve the optimum output of grain yield, availability of optimum supply of nutrients, and control weeds excellently with this depth and with using herbicides.

The fourth step for gaining high crop yield and improving productivity is the management and quality of chemical spraying to avoid or minimize the losses due to pests and diseases to the least limit. Huge competition faces the crop with weed and weedy rice, these species fight for space, water, and nutrient. Insects are big harm to the crop, outbreaks of pests and diseases such as brown planthopper (BPH) or Stem Borer could destroy the whole crop or at least make huge losses of the crop yield that distress the farmers. So, farmers should be aware that their crops should be always and all-time be protected in every small area and every individual plant. The major challenges that face agricultural production are the losses of yield caused by pathogens, pests, and weeds (Oerke and Dehne, 2004). Reducing and minimizing pest and insects' impact on the crop is believable to add significantly to the global harvested quantity and quality of rice. Rice faces more than 100 known kinds of pests including insects, fungal diseases, and weeds, these pests can cause significant and severe damage to the rice plant, and as mentioned above there are some insects and diseases that can destroy the entire whole harvest crop. Proper and quality pesticide spraying is very important for agricultural crop production with the protection of human health. Quality pesticide applications depend on the quality of pesticides product of the active ingredient, which achieves the goal of elimination of pests without causing unacceptable effects if it is used as the recommended amount using the recommended machine and in a recommended amount of water to solute the chemical. Nowadays, agricultural crop production relay mainly on pesticides to reduce losses caused by insect pests, diseases, and weeds which could reduce the quantity and quality of harvestable products markedly. All other traditional means and even biological methods do not realize the target.

The fifth step to raise the crop yield and increase production is perfect fertilization and adequate plant nutrition management. Fertilizer should give to the plant when it needs it, so the right time of fertilizer application is among the main roles that affect the quality of fertilization and could achieve high and beneficial output. Fertilizers need high control to guarantee uniform distribution in the field. As a result of low-quality control, deficiency and high costs are being incurred. To achieve the highest potential crop yield, an adequate amount of fertilizer should be distributed in the intended area uniformly. Fertilizer distributed in a non-uniform way in the field leads to inequality of fertilizer distribution and all the plants may not get the required nutrients. Farmers should use the efficient rates of fertilizer applications at the appropriate timing to increase crop productivity and maintain the environmental sustainability. To ensure high fertility uptake by the plant, it is better to apply granular fertilizer in many splits in several and

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different times according to the growing stage to ensure that the plant takes the adequate amount of needed fertilizer at the suitable timing without insufficient infertility at the critical stages of growth, tillering, panicle initiation, heading, and grain filling.

The sixth step to realizing and achieving the targeted rice yield and quality is harvesting in a high-quality performance. Harvesting is one of the most important activities to sustain the productivity and quality of rice. Nowadays, combine harvesters have been playing an increasingly important role in modern agricultural production in recent years, they are being employed massively and continuously in harvesting rice in Malaysia. Harvesting and threshing, play an important role to reduce postharvest rice losses of the fully matured rice crops and the quality of milled rice as well (Chandrajith, et al.,2016). The loss rates are important factors in harvesting, but also the quality of rice is a major concern. To produce the highest quality and quantity of rice possible, the effects of combine operating parameters over the entire range of rice conditions are required. Grain losses due to harvesting with a combine harvester are one of the main focuses regarding waste and loss control, they are important parameters to weigh the performance of a combine harvester. The harvest system should perform with a minimum loss, maximum efficiency, and maximum return for all involved. The cleanliness and healthy condition of the product are primary concerns for rice consumption. The combine harvesters should not cause negative impacts on the quantity and the quality of paddy grains which will seriously affect the profitability of the crop.

The performance of the combine harvester should work in trend for reduced grain losses. Grain losses during harvest represent a direct loss of income for the farmers. In some countries, it is perceived that reasonable small grain loss should reach a maximum of 3 % of the total crop yield. It is very important to determine total losses and quality of harvested mass in the rice harvest combines, not only in terms of economic calculation and determination of total yield and the effects of the harvester but also for informing users when harvesters are rented or are engaged in the machinery rings. The concept of machinery rings extends beyond the sharing of farm machinery and includes access to other resources such as farm labor, competitively priced commodities, farm supplies (e.g. fuels, fertilizer, seed), and training. The introduction of combined harvesters in the technological process of rice harvesting is to reduce the total losses and raise quality harvested mass, which also, means a higher yield of rice in the harvester bunker (Barać et al.,1990).

1.2 The Concept of Quality

Quality control in all agricultural production operations is difficult to achieve perfection. In manufacturing system, quality control started earlier, but in agriculture, till this day it cannot say there is a known system for quality control that farmers can follow, just a regional trial and not completed system such as total quality management system (TQM) that is already applied in the industrial sector. In agriculture, this needs more research, there are huge variations in materials, machines used, the timeline of operations, quality, and efficiency of operation implementation, and the skills and education of the operators and employees, besides their concern about quality control as these peoples want just to

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finish their jobs in any way and do not look to the results and outputs, farmers probably do not give the activity the required care that it deserves. Also, this sector needs a uniform comprehensive, and completed standard that farmers are forced to follow. Nowadays, there are many standards in Malaysia concerning agriculture such as MyGap, Rice Check, and ISO, but still, all these standards do not cover all issues in crop production operations.

The practices and operations aim to ensure that the production of crops through all agricultural operations is carried out according to the standard specifications to ensure farmers use the right source of materials and machines, with the right amount not lesser not more, at a right time not before and not delaying it and put all that in the right place not out of the small intended place to achieve the aim of operations, and to avoid wasting of resources, after all, which produce the product that the of customers need and satisfy. The fact, is now there is no process of inspecting the output of any agricultural operations if they meet the required quality standards or not. Agricultural practices and operations need to be checked during and after the completion of the agricultural production operation's weaknesses and faults. Inspection of quality is achieved by measuring and evaluating the output of operations for every field taking random samples that are appropriate to the type of operation quality. The quality control's main objective is to check and ensure that the farming system follows the standard, and is achieved by using inspection. The quality control system could be achieved through inspection and then making corrections procedures. The Plan-Do-Check-Act (PDCA) cycle is the operating principle of all quality management systems. Plan to establish objectives and draft the plan, do: implement the plans, check: measure and monitor the actual results against the planned objectives, act: correct and improve the plans to meet and exceed the planned results. Inspection is intended for quality control to prevent and avoid faults that could affect the crop product. Farmers could be inspectors for their farms check during and after the operations and make corrections procedures.

1.3 Problem Statement

The challenges keys facing farmers today are improving rice productivity and grain quality, so they could increase their income if they achieved this. The main factors that affect the rice crop yield are the selection of good hybrids seed variety, weeds and weedy rice, the infestation of pests and diseases in the field, managing water irrigation inefficiently, and climatic changes. Farmers do not understand the contribution of each factor to overall rice crop yield production and grain quality, and they do not have selected strategies to integrate high quantity with high quality.

Farmers till the soil because they used to do so, but the problem is they do not know what the limit and amount of soil loosening and inversion they should do. The soil in Sungai Burong is fine textured and very soft soil, the moisture content is always very high, and the soil does not need more loosening because it already loosened, but farmers keep plow the soil three times every season, this plowing loosens the soil too much and that affects the other operations such as mechanical transplanting that come after tillage, besides the loosened soil prevent strong contact between the plant and the soil which may affect the

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uptake of mineral material and fertility. The reason that the soil is too loosened is that the farmers do not follow Rice Check recommendations in terms of water drainage before harvesting, this makes water drainage after harvesting impossible, and this leads to submerging the soil for a long time leads to softening and loosening the soil. Farmer's practices do not result in the optimal soil physical properties, which is required for planting operation and plant growth, and thus affect the crop yield by reducing planting density and reducing fertility uptake. So, tillage does not achieve its aim.

Puddling harms the topsoil layer by loosening it more than the required level because the puddling operation performed in very high moisture content, it also, consumes a large quantity of the total water requirement in rice because farmers flood the field up to 10 cm for more than 2 days avoiding following Rice Check standard requirement. For efficient working of self-propelled rice transplanting machine, a suitable puddle soil condition, degree of puddling, an optimum depth of puddling, optimum bulk density, the standardized water depth, and soil strength of the puddle wheel should be done following the standard. This affects the spacing of transplanted paddy in the rows and between rows, the number of planting seedlings within the hill, degree of vertical standing, and depth of planting which should be maintained within the standardized system to obtain high quality of transplanting.

Farming planting practices do not achieve the required planting density and spacing, for transplanting the soil conditions affect their performance and that lead to planting missing, number of hill per square meter, number of seedlings/hill and number of seedlings/m^2, is not done as the required. Also, the field condition affects the row spacing which is not adjustable, and the distance between the plants, which were calculated based on previous research, so any negative effect could affect the performance of planting growth. The field condition and land preparation affect also the depth of planting and the planting angle which affect plant growth. So, the imperfection of land preparation is the main reason for the weakness of mechanical transplanting performance.

Farmers do not care about the required schedule of water irrigation for the rice plant and the required depth of water. Many times during the season, plants suffer from insufficient and inadequate water, which affects the grain yield. Also during fertilizers broadcasting and pesticide spraying operations, all the gates in or out of irrigation or drainage should be closed, but in reality, many times during these operations the gates were open because farmers forgot that. Also, the farmers do not keep the depth of water at the required level during these operations, which affects the quality of operations especially during fertilizer broadcasting operations, and that share and cause fertility losses. Improve water control by better irrigation and drainage to achieve full potential yield rice is missing in the farming system. Producing optimum rice yields through continuous flooding irrigation with 10 to 15 cm of water depth is optimum for fertility efficiency, fighting weeds, grain filling, and high grain yield. Land leveling also affects the uniform and even distribution of the water in the field.

Farmers do not use the efficient rates of fertilizer applications in the appropriate timing, and in the right places which could share in increasing crop productivity and maintaining

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environmental sustainability. Farmers apply fertilizers in a split way and in many times, but the applications periods are very closed which causes the plant to take the greatest amount of fertility earlier, besides, there would be times and stages that plant need nutrition, but there was no more application because the fertilizer is already applied before, so the timing is very important and also, the applying of enough amount during the important stage tillering, panicle initiation and grain filling. One of the problems related to the fertilizer application is that the broadcasting operators do not achieve the fertilizer broadcasting operations quality through the evened and uniformed distribution of granular fertilizer, this is an important factor that guarantees the success of agriculture (Cunha and Soares Filho, 2016), the operator does not perform the distribution in a uniform and accurate way, so the fertilizer does not reach the right place, some plant could not get the adequate amount of fertility. The perfection of fertilizer performance affects crop production (Sanaeifar and Sheikhdavoodi, 2012). The farmers do not follow perfectly the schedule and they do not use chlorophyll meter or leaf color chart LCC to determine the actual needs of the plant and perform the application based on that. The fertilizer should apply following the four rights, right source, the right amount, right time, and right place, but unfortunately, they do not follow that.

Farmers do not monitor and examine their plants closely to diagnose the nature and source of pests and diseases accurately and evaluate the problem for specific needs management to their paddy plots, but they just follow a traditional schedule and practices to do so. Synthetic pesticides should be used at a specific time in the pests' life cycle. Farmers should spray with the least toxic, most effective, and most pest-specific chemicals available. The timing of chemical applications is critical to effective pest control. Farmers should carefully read the manufacturer’s instructions label about how to use the product and how often they should spray. The objective of pesticide spraying operations is to put an adequate amount of the effective active ingredient in a uniform dose to the target in the suitable time of the pest life cycle in an environmentally friendly and safe. Cost-Effective control of insect pests and diseases could be achieved, if the population of pests reaches the known Economic Threshold Level (ETL), a pesticide product with the right action mode should be used. Satisfied control depends on several factors such as choosing suitable equipment including the spraying machine and the working nozzle, application timing, size of the droplet, level of drift, coverage percentage, penetration index, and ratio. One problem of the current practices is the uneven and ununiformed distribution of the chemical spraying solution irregularly in the field which may affect the controlling of the damaging pests and diseases, especially those located and live at the lower part of the plants, where spraying deposition and cover amount of chemical spraying are not effective and enough, besides increase spray drift which reduces the quality of spraying. The farmers and spray operators do not consider the weather status and field conditions for specific local and temporal situations, which comprise a set of uncontrollable factors able to impair application efficiency and that should be taken into consideration (Doruchowski et al, 2013). The weather situation affects the quality of spraying and increases the spraying drift.

Increasing rice production, rice yields, and reducing losses caused by pests and diseases could be achieved through controlling pests, weeds and weedy rice effectively is the main objective of quality pesticide spraying operation. Farmers do not examine the plant damaged by pests across the rice field before and after the pesticide applications and do

not avoid outbreaks of disease and pests. They should spray the intended area with recommended pesticides following Rice Check Economic Threshold Level (ETL), but they just follow the traditional schedule, they rarely make a visual examination of the crop for defected grain by diseases and insects or review and record plant damages by pest survey and control. Sustainable pest and disease management reduce losses and costs while minimizing on-farm and off-farm health and environmental impacts.

In harvesting, farmers do not care or measure the harvesting losses rate which is an important factor, besides the quality of rice as a major concern which is also negligible. Farmers do not evaluate or even care about the effects of combine operating parameters over the entire range of rice conditions, which is required to produce the highest quality and quantity of rice possible by reducing harvesting loss, increasing the whole healthy grain percentage, and reducing the damaged grain and the materials other than grain (MOG). It is worth, mentioning that by using Service Providers, farmers have no choice and have to rush for harvest even with a low level of maturity. Grain losses due to harvesting with a combine harvester are one of the main focuses regarding waste and loss control, they are important parameters to weigh the performance of a combine harvester. The harvest system should perform with the least loss, least grain damage, least dockage, and materials other than grain (MOG), with maximum efficiency and maximum return for whole healthy grain. Farmers and also the drivers do not aware that the combine harvesters should not cause negative impacts on the quantity and the quality of paddy grains, which will seriously affect the amount of produced grain, the profitability of the crop, and quality operation. The mean of the total grain losses is more than 3%, which is higher than the standard. The percentage of damaged grains such as husked and broken grains is not lesser than 1%. The percentage of materials other than grain (MOG) is not lesser than 1% of the total grains.

In this study, Rice Check used as a benchmarking standard for the farming practices and operations, and that because Rice Check is a comprehensive standard that includes all agricultural operations quality keys in perfect scheduling showing the source of materials, tools, and machines, the amount of material and machines that should be used, in a detailed time to cover specific placing. MyGap just gives instructions for using pesticides, fertilizer, and soil conservation in a way that does not harm the product and the environment. ISO 22006 includes guidelines for the application of ISO 9001:2008 to crop production, it focused mainly on customer satisfaction and record of all agricultural activities, it has some strong points but it is more generalized not in detail as same as Rice Check.

1.4 Research Objectives

The main objective of the study is to evaluate the current status of quality management in paddy cultivation by measuring and evaluating each component in all agricultural operations and practices in terms of accuracy, effectiveness, quality, compliance with applicable standard Rice Check.

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Specific Objectives:

1. To evaluate the quality of agricultural practices and operations in wetland rice cultivation based on the existing national standards Rice Check.

2. To rank the agricultural parameters based on the effectiveness of rice yield, and determine the most effective key parameter for improving the quantity production in wetland rice cultivation.

3. To use data envelopment analysis (DEA) to minimize the effective inputs with fixed quantity production, and maximize the quantity production with fixed effective inputs. Then validate the two optimization models.

1.5 Scope of the Study

Paddy in Malaysia is cultivated in lowland (wetland) and upland (dryland), this study is limited to lowland paddy fields. The study area is in Sungai Borung in east-west Selangor the best area in rice productivity and yield. These plots under study were chosen because the farmers are concerned about their farms and keep records of their agricultural activities, have a good education level, and show their willingness to cooperate. There are two seasons in Malaysia, main season (dry season) and off-season (wet season), this study included both seasons, main season in 2017 and off-season in 2018. Farmers in Malaysia cultivate paddy using both transplanting and direct seeding cultivation, this study includes both systems, transplanting and direct seeding. For transplanting paddy, this study did not include the nursery stage because the farmers do not plant seedlings on their farm, they just buy it from producers. Both broadcasting and transplanting systems are performed on puddled soil. Farmers practicing during every season known operations namely slashing or burning the straw, pre-spraying, tillage, planting (broadcasting or transplanting), water irrigation, paddy embroidery, fertilizing, spraying, weeding, drainages and harvesting. The research is, however, limited to evaluating all operations mentioned above that were practiced by farmers in the study area. The study does not include leveling because farmers do not level their fields regularly. Malaysian Rice Check was used to evaluate the quality of farming practices and determined the quality index based on the four rights (4Rs) the right source, the right amount, the right time, and the right place. Rice Check has a detailed schedule that contains the type of materials, machine, and tools, the amount of materials, the time of operation, and the place that should be covered. To develop quality assessment, the study utilized data collected from operations (tillage, planting, irrigation, fertilizing, spraying, and harvesting) because of their relationship with paddy yield. The study includes using a mathematical model for optimizing the inputs of fertilizer because it is the main factor that affects the paddy output.

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