UNIVERSITI PUTRA MALAYSIA

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A DECISION SUPPORT SYSTEM FOR RICE CULTIVATION ON ACID SULFATE SOILS

By

TOTOK SUSWANTO

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

January 2005

Dedicated to

My Parents

My lovely wife,
Ermina Sari

My lovely son,
Nabiha Tegar Suswanto

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

A DECISION SUPPORT SYSTEM FOR RICE CULTIVATION ON ACID SULFATE SOILS

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January 2005

Chairman : Professor J. Shamshuddin, PhD

Faculty : Agriculture

Acid sulfate soils pose chemical, biological and physical problems for rice cultivation. The proposed amelioration for the study includes: 1) correct water management; 2) applying lime at appropriate rate and time; and 3) adequate fertilizer application. Those procedures were organized into an integrated decision support system (DSS), which used analytical methods and models. Main component for the model was production function as a response of those amelioration processes. The model used that function to simulate yield and in advance step, doing micro economic analysis by calculating profit in order to find the maximum one.

In delivering production function, glasshouse experiment has been conducted using soil from acid sulfate soil area in Jelawat Rusa Irrigation Scheme, under Project Kemasin-Semerak (PERKASA), Kelantan. The result of glasshouse experiment showed that yield was significantly affected by the combination of lime and fertilizer

(P<0.02). Water management and any of its combination did not affect yield. The highest yield was found on combination of GML at rate 4 t/ha using maximum fertilizer rate. Ameliorative assessment of lime and fertilizer have improved yield shown by increased soil quality and a better plant performance. Liming has increased soil pH, exchangeable Ca and exchangeable Mg, and these have decreased toxicity caused by of Al and Fe. Liming and water management has also improved rice yield by increasing grain weight and decreasing empty spikelet number.

Field experiments, which include experimental plot and demonstration plot, have been conducted in that area for 2 seasons with the purpose of validating glasshouse experiment. Statistical analysis showed that yield of plot experiment on the first season was not significantly different (P>0.12). It was primarily because the first season of field experiment was disturbed by flood due to high rainfall and poor drainage system at the location. It may be also because lime is still not stably interacted with the soils to increase soil pH. Crop cutting test (CCT) in the second season of the field experiment showed a significant effect of lime treatment on the yield (P<0.07). The highest yield of 7.52 t/ha was found on treatment 6 using application of GML at 4 t/ha in combination with organic-based fertilizer (JITU). Treatment 5 using application of GML at 8 t/ha resulted on yield of 7.22 t/ha, which was not different from treatment 6 and this become the second highest value. Using field experiment, field adjusting factor (FAF) has been developed. It showed percentage of achieved yield on field trial from the potential yield (glasshouse experiment). The value of FAF was 0.40, which means only 40% of potential yield will be gained on the field. The 60% loss may be because of technical problems, inefficient harvester machines, incorrect fertilizer applications, pest and disease damages.

Response curve as production function was formed using TableCurve 3D v4.0. From surface fitting process, an equation has been found ($P<0.01$). It consists of 4 parameters which were also significant at the same α of 5.00%. The value of r^2 of the equation was 0.71, while the curve on initial data and the equation is quite similar.

A model, RiCASS, used predicted yield from the equation to calculate the cost of inputs both fixed and variable, and to calculate the profit. It ran simulation under various inputs to find the optimum level that result in maximum profit under 4 different scenarios. Simulation showed that for the first general scenario, maximum profit margin was found to be $ 2,847/ha from predicted yield at 6.15 t/ha. It used lime at the rate of 6.50 t/ha and fertilizer index of 10. The second scenario in which total cost was limited to RM 1,500, maximum profit was found to be RM 2,024. Based on farmer's cost, the maximum profit was found to be RM 3,624, while under limitation of cost below RM 1,000, the profit was found at RM 3,263.

Validation carried out to evaluate the equation which consisted of paired comparison t-test and mean estimation error. Result showed that the equation was able to represent actual yield shown by insignificant difference with field experiment yield (average $P>0.20$) and small estimation error (2%).

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Masters Sains

SISTEM PENUNJANG KEPUTUSAN UNTUK PENANAMAN PADI DI TANAH ASID SULFAT

Oleh

TOTOK SUSWANTO

January 2005

Pengerusi : Professor J. Shamshuddin, PhD

Fakulti : Pertanian

Tanah asid sulfat menimbulkan masalah kimia, biologi dan fizikal untuk penanaman padi. Pemuliharaan yang diusulkan dalam kajian ini meliputi: 1) pengurusan air yang betul; 2) penggunaan kapur pada kadar dan masa yang sesuai dan 3) penggunaan baja yang mencukupi. Prosedur tersebut boleh dikumpulkan kepada sistem penyokong keputusan terintegrasi (DSS), yang menggunakan kaedah analisis dan model. Komponen utama model adalah fungsi produksi sebagai tindakbalas kepada proses pemuliharaan tersebut. Model menggunakan fungsi tersebut untuk mensimulasi hasil pengeluaran dan pada langkah selanjutnya, melakukan analisis kewangan dengan mengira keuntungan bagi mendapatkan tahap yang maksimum.

Untuk membuat fungsi produksi, kajian rumah kaca telah dijalankan dengan menggunakan tanah dari kawasan asid sulfat di Rancangan Pengairan Jelawat Rusa, di bawah Projek Kemasin Semerak (PERKASA), Kelantan. Hasil dari kajian rumah

kaca menunjukkan bahawa hasil pengeluaran dipengaruhi oleh kombinasi dari faktor kapur dan baja ($P<0.02$). Pengurusan air dan semua kombinasinya tidak mempengaruhi hasil pengeluaran. Hasil pengeluaran paling tinggi diperolehi dengan menggunakan GML pada kadar 4 t/ha pada kadar baja maksimum. Pembaikpulihan dengan menggunakan kapur dan baja telah meningkatkan hasil pengeluaran dengan pembaikan pada kualiti tanah dan tanaman. Pengapuran telah meningkatkan pH tanah, Ca tukar ganti, Mg tukar ganti dan ini menurunkan toksikan Al and Fe. Pengapuran dan pengurusan air juga telah meningkatkan hasil pengeluaran dengan peningkatan pada berat bijian dan penurunan pada jumlah spikelet kosong.

Kajian di ladang, yang terdiri dari plot kajian dan plot demonstrasi, telah dilaksanakan pada kawasan tersebut untuk 2 musim dengan tujuan melakukan pengesahan terhadap kajian rumah kaca. Analisis statistik menunjukkan bahawa hasil pengeluaran dari plot kajian pada musim pertama tidak terlalu berbeza ($P>0.12$). Hal ini disebabkan musim pertama dari kajian telah diganggu oleh banjir kerana taburan hujan yang tinggi dan sistem pengairan yang tidak baik. Hal itu mungkin juga disebabkan kapur yang masih belum stabil berinteraksi dengan tanah untuk menaikkan pH. Musim kedua dari kajian ladang menunjukkan bahawa CCT pada plot kajian menunjukkan kesan tindakbalas kapur yang berarti ($P<0.07$). Nilai yang tertinggi ada pada rawatan 6 yang menggunakan GML pada 4 t/ha dengan baja organik (JITU). Rawatan 5, menggunakan GML pada 8 t/ha, tidak terlalu berbeza dengan rawatan 6 dan ianya merupakan nilai tertinggi kedua. Faktor koreksi ladang (FAF) telah dirumuskan dari pada kajian di ladang. Nilai itu menunjukkan kadar hasil pengeluaran dari ladang yang diperolehi dibandingkan dengan hasil pengeluaran potensi (kajian rumah kaca). Nilai FAF adalah 0.40 yang bererti hanya 40% dari hasil pengeluaran potensi akan dicapai di ladang. Baki 60% hilang adalah kerana masalah teknik, mesin penuai yang tidak efisien, penggunaan baja yang tidak sesuai, hama dan penyakit.

Lengkuk sebagai fungsi produksi telah dibina dengan menggunakan TableCurve 3D v4.0. Dari proses *fitting*, persamaan telah diperolehi dengan bererti ($P<0.01$). Persamaan itu terdiri daripada 4 parameter yang juga bererti pada α yang sama 5.00%. Nilai r^2 dari persamaan adalah 0.71 manakala lengkuk data permulaan dan lengkuk dari persaman cukup serupa.

RiCASS yang menggunakan pengiraan hasil pengeluaran dari persamaan tersebut mengira kos tetap dan kos pemboleh-ubah dan mengira keuntungan. RiCASS melakukan simulasi dengan berbagai tahap input untuk mencari nilai penggunaan yang optimum dimana ianya menghasilkan keuntungan maksimum dengan 4 pendekatan yang berbeza. Simulasi pada pendekatan umum pertama menunjukkan maksimum keuntungan pada RM 2,847/ha dari perkiraan hasil pengeluaran pada 6.15 t/ha. Hasil itu dicapai dengan menggunakan kapur pada kadar 6.50 t/ha dan indeks baja 10. Pendekatan kedua dimana kos total di bawah RM 1,500, keuntungan maksimum diperolehi ialah pada RM 2,024. Berdasarkan pengeluaran petani, keuntungan maksimum diperolehi pada RM 3,624 manakala dengan batasan biaya di bawah RM 1,000, keuntungan maksimum diperolehi pada RM 3,263.

Pengesahan telah dijalankan untuk menilai persamaan yang terdiri dari perbandingan berpasangan t-test dan *mean estimation error*. Hasil menunjukkan bahawa persaman boleh mewakili hasil pengeluaran sebenar, ditunjukkan dengan perbezaan yang tidak bererti model dengan hasil pengeluaran sebenar (purata $P>0.20$) dan estimasi kesalahan yang kecil (2%).

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I certify that an Examination Committee met 26th January 2005, to conduct the final examination of Totok Suswanto on his Master of Science thesis entitled "A Decision Support System for Rice Cultivation on Acid Sulfate Soils" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

TOTOK SUSWANTO

Date: 20 APRIL 2005

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CHAPTER 1

INTRODUCTION

1.1 Background

In Peninsular Malaysia, about 500,000 ha of acid sulfate soils occur in the coastal regions. Several agricultural projects and research have been carried out to alleviate problems of these acid sulfate soils for crop production. One of them is the Kemasin-Semerak Integrated Agriculture Development Project (IADP) which was launched in 1981 in Kelantan. Kemasin-Semerak IADP is the Malaysian Government project with the objectives of flood mitigation and improvement of agriculture productivity.

One area in the Kemasin-Semerak IADP that has been earmarked for rice cultivation is the Jelawat Rusa Irrigation Scheme. In this area, agriculture productivity has been slowly deteriorating due to land degradation, which is partly caused by incorrect management practices. Water resource in the area is acidic, containing toxic amounts of Al and Fe. The acidity is presumably generated by pyrite (FeS_2) undergoing oxidation when it is exposed to the atmosphere after the soils have been drained to make way for agriculture.

Acid sulfate soils pose chemical, biological and physical problems for crops. Chemically, acid sulfate soils have the following agronomic problems: 1) direct effect of severe acidity – primarily the increased solubility and toxicity of aluminum and iron (Fe^{3+}); 2) decreased availability of phosphate; 3) low base status and nutrient deficiencies; and 4) salinity problems. Under flooded conditions, acidity is reduced, but new problems occur such as: 1) iron (Fe^{2+}) toxicity; 2) hydrogen sulfide toxicity; and 3) CO_2 and organic acid toxicity. Physical soil problems that arise mainly through the inhibition of root development in acid sulfate horizons are water stress and blocked field drains by iron oxide deposits (Dent, 1986). In a review of the literature on soil chemical properties and their relation to the growth of rice in acid sulfate soils, Satawathanant (1986) reported adverse effects of H^+, toxicities of Fe, Al and sulphide, electrolyte stress, CO_2 and inorganic acids.

Ameliorative steps are needed to put the land into productive use. The several steps of ameliorations are: 1) correct water management to prevent pyrite oxidation by maintaining water table level above the pyrite layers; 2) applying lime and/or organic matter at appropriate rate and time; 3) adequate fertilizer application; and 4) in the case of rice, keeping the soil submerged as long as possible before transplanting.

These procedures can be organized into an integrated decision support system (DSS) which using analytical methods and models. The system can help decision makers and farmers formulate the best solutions in cultivating rice on acid sulfate soils to produce high yields and the maximal profit. The main users of the system are government, agencies, scientists, researchers, farmers and students.