



**UNIVERSITI PUTRA MALAYSIA**

**IMPACT OF CATTLE GRAZING ON SELECTED ENVIRONMENTAL  
VARIABLES IN PASTURE-BASED LIVESTOCK PRODUCTION  
SYSTEM**

**MAJID AJORLO**

**FPAS 2010 4**



**IMPACT OF CATTLE GRAZING ON SELECTED ENVIRONMENTAL  
VARIABLES IN PASTURE-BASED LIVESTOCK PRODUCTION SYSTEM**

**By**

**MAJID AJORLO**

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

**December 2010**



*To*

*My wife Mahboubeh for her love, patience and wholehearted support*

*My lovely son Ahoora for making everything worthwhile*

*The soul of my beloved father-in-law in heaven*

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

**IMPACT OF CATTLE GRAZING ON SELECTED ENVIRONMENTAL VARIABLES IN PASTURE-BASED LIVESTOCK PRODUCTION SYSTEM**

By

**MAJID AJORLO**

**December 2010**

**Chairman: Associate Professor Ramdzani b. Abdullah, PhD**

**Faculty: Environmental Studies**

Livestock production system has been developed to meet the increasing demand for ruminant products in Malaysia, however, few studies have focused on the assessment of the impact of such production system on the environmental variables such as soil, vegetation and surface water. With increasing demand for livestock products which resulted in the development of livestock production system, quantification and understanding of the environmental impacts of livestock production are necessary prerequisites for any effective planning to enhance environmental quality. This study aims to assess the impacts of short-term (2-year) heavy and long-term (33-year) moderate grazing by cattle on the quality of soil, vegetation and surface water in communal native and commercial improved tropical pasture ecosystem at both the farm and catchment scales. The study was conducted at the Universiti Putra Malaysia Livestock Section, about 20 km south of Kuala Lumpur, Malaysia. Two study sites, the Ladang 2 farm (3° 00' 28"N; 101° 42' 10"E) and the TPU catchment (2° 58' 53"N; 101° 43' 38"E), represented a native and improved pastures, respectively. Water samples from a year-round monitoring of streams in the pastures with cattle grazing and



ungrazed enclosure were analyzed for water quality parameters of EC, DO, pH, NH<sub>3</sub>-N, COD, TSS, Fecal Coliform (FC), and *E. coli*. Soil chemical characteristics such as pH, EC, OC, TN, AP, exchangeable cations, and heavy metals (Cd, Pb, Cu, Cr, Fe, Zn, and Mn) were analyzed. Infiltration rate, bulk density, penetration resistance, moisture content and porosity were determined to assess alterations in soil physical properties. A combination of both systematic and randomized method was used to measure pasture vegetation and invasive species. Root morphological and distribution characteristics were measured using soil coring approach. Water quality data were analyzed with the multivariate analysis of variance, multivariate statistical techniques and the Harkins' index. Soil chemical and physical properties and root morphological data were analyzed with the repeated measures analysis of variance. The multivariate analysis of variance was used to analyze pasture vegetation and invasive species data. The results showed that the streams of the TPU catchment were classified as classes II and I in the grazed and ungrazed pastures, respectively. Streams in both the grazed and ungrazed sites were classified as class II in 'Ladang 2' farm. Significant difference between the grazed and ungrazed treatments was observed for water quality variables of TSS, COD and FC at the Ladang 2 farm. DO, BOD, pH, EC, TSS, COD, NH<sub>3</sub>-N, FC and *E. coli* varied significantly between the grazed and ungrazed pasture in the TPU catchment. The study also revealed that the moderate grazing led to higher soil pH, EC, AP and Mg<sup>+2</sup> and lower TN, OC, Ca<sup>+2</sup> and K<sup>+</sup> at the improved pasture. Higher levels of pH, EC, OC and lower concentrations of AP, TN, Ca<sup>+2</sup> and Mg<sup>+2</sup> were observed at the native pasture. Moderate grazing had significant effect on heavy metal concentrations in soils, but heavy grazing did not lead to a significant accumulation of heavy metals in the soils. Contrary to the heavy grazing, moderate grazing had no negative impacts on soil physical properties. Moderate grazing increased grasses

regrowth rate and herbage mass yield; while heavy grazing had no significant effect on those characteristics. Moderate grazing affected the invasive species population adversely; however heavy grazing provided relatively desirable condition for their establishment and infestation. Mean root diameter, surface area and volume densities were not affected by moderate grazing in the improved pasture. However, root surface area and mass densities were affected at heavily grazed native pasture. Grass roots were significantly affected by heavy grazing at native pasture, but unaffected by moderate grazing at the improved pasture. The results indicated that cattle grazing affect the surface water in pasture ecosystem adversely. Cattle grazing effects on soil chemical characteristics depend on the type of elements, which may increase or decrease over time. Soil heavy metals content can increase in pastures where cattle have been grazing for a long-term. Moderate grazing can influence pasture production positively and decrease the invasive species. Pasture plant roots were not adversely affected by either short-term heavy or long-term moderate grazing intensities.

**Keywords:** Water quality, Vegetation cover, Invasive species, Root morphology, Soil chemical properties, Soil physical properties, Heavy grazing, Moderate grazing

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**KESAN PENGELUARAN TERNAKAN LEMBU MELALUI SITEM YANG  
BERASASKAN PADANG RAGUT TERHADAP ALAM SEKITAR**

Oleh

**MAJID AJORLO**

**Disember 2010**

**Pengerusi: Profesor Madya Ramdzani b. Abdullah, PhD**

**Fakulti: Pengajian Alam Sekitar**

Berikutan peningkatan di dalam permintaan untuk produk ternakan yang dihasilkan melalui pembangunan sistem pengeluaran ternakan adalah sangat penting untuk mencari keseimbangan yang bersesuaian antara pengeluaran ternakan dan persekitarannya. Kajian ini bertujuan untuk menilai kesan pemeliharaan ternakan di atas padang ragut dalam jangkamasa pendek (2-tahun) secara berlebihan dan kesan jangkamasa panjang secara sederhana (33-tahun) terhadap kualiti tanah, tumbuh-tumbuhan dan kualiti air permukaan tanah di kawasan padang rumput asli dan juga peningkatan ekosistem padang ragut tropika di kedua-dua peringkat ladang dan kawasan tadahan. Kajian ini telah dijalankan di Bahagian Ternakan, Universiti Putra Malaysia, sekitar 20 km ke selatan Kuala Lumpur, Malaysia. Dua lokasi kajian iaitu kawasan Tadahan TPU ( $2^{\circ} 58' 53''\text{N}$ ;  $101^{\circ} 43' 38''\text{E}$ ) dan kawasan Ladang 2 ( $3^{\circ} 00' 28''\text{N}$ ;  $101^{\circ} 42' 10''\text{E}$ ) telah dinilai dan masing-masing telah menunjukkan peningkatan yang berterusan di padang ragut yang ditingkatkan dan juga di padang ragut asli. Persampelan air telah diambil dari alur di padang ragut sepanjang tahun di

kawasan ragut dan di kawasan ragut yang terkepung dan dianalisis bagi parameter kualiti air seperti EC, DO, pH, NH<sub>3</sub>-N, COD, TSS, Fecal Coliform (FC), E. Coli dan sebagainya. Ciri-ciri kimia tanah juga telah dianalisis seperti pH, EC, OC, TN, AP, kation boleh tukar dan logam-logam berat (Cd, Pb, Cu, Cr, Fe, Zn, and Mn). Bagi mengukur perubahan di dalam ciri-ciri fizik tanah, kadar penyusupan, ketumpatan pukal, rintangan penusukan, kandungan lembapan dan keliangan telah diambilkira. Kombinasi kaedah secara sistematik dan rawak telah digunakan bagi mengukur ciri-ciri tumbuh-tumbuhan serta spesis penceroboh di padang ragut tersebut. Ciri-ciri morfologi akar dan juga pengagihannya telah diukur menggunakan pendekatan penerasan tanah. Keputusan kajian telah menunjukkan bahawa alur di kawasan tadahan TPU tergolong di dalam kelas II dan kelas I (mengikut indeks Harkin) masing-masing di kawasan ragut dan di kawasan tidak diragut. Alur di kawasan ragut dan tidak diragut pula tergolong di dalam kelas II di Ladang 2. Perbezaan yang signifikan diperolehi di kawasan yang diragut dan tidak diragut terhadap tiga pembolehubah untuk kualiti air di Ladang 2 iaitu TSS, COD dan FC. Manakala DO, BOD, pH, EC, TSS, COD, NH<sub>3</sub>-N, FC dan E. Coli menunjukkan perbezaan yang signifikan di antara padang yang diragut dan padang yang tidak diragut di kawasan tadahan TPU. Pengembalaan ternakan dalam jangkamasa panjang secara sederhana boleh mengakibatkan ciri-ciri tanah seperti pH, EC, AP dan Mg<sup>+2</sup> meningkat tetapi sebaliknya berlaku (iaitu penurunan) untuk kepekatan TN, OC, Ca<sup>+2</sup> dan K<sup>+</sup> di padang ragut yang ditingkatkan. Pemerhatian di padang ragut asli menunjukkan kepekatan yang tinggi bagi pH, EC dan OC, tetapi sebaliknya kepekatan yang rendah telah didapati bagi AP, TN, Ca<sup>+2</sup> dan Mg<sup>+2</sup>. Pengembalaan ternakan dalam jangkamasa panjang telah memberi kesan terhadap kepekatan logam-logam berat di dalam tanah. Sebaliknya, pengembalaan ternakan dalam jangkamasa pendek secara berlebihan



tidak mengakibatkan pengumpulan logam-logam berat secara signifikan di dalam tanah. Berbeza dengan penggembalaan secara berlebihan, penggembalaan secara sederhana tidak memberi kesan negatif terhadap ciri-ciri fizik tanah di dalam kajian ini. Penggembalaan secara sederhana boleh meningkatkan kadar pertumbuhan semula rumput dan penghasilan herba yang banyak; manakala penggembalaan secara sederhana tidak memberi kesan terhadap ciri-ciri tersebut. Penggembalaan secara sederhana memberi kesan buruk terhadap populasi spesis penceroboh; bagaimanapun secara relatifnya penggembalaan secara berlebihan menyediakan keadaan yang bersesuaian untuk pembentukan dan serangan spesis penceroboh. Disamping itu, penggembalaan secara sederhana di padang ragut yang sudah ditingkatkan tidak memberi kesan terhadap min garispusat akar, luas permukaan dan ketumpatan isipadu. Namun begitu, penggembalaan secara berlebihan di padang ragut asli memberi kesan kepada luas permukaan akar dan ketumpatan jisim. Bahagian rumput bawah tanah secara signifikannya dipengaruhi oleh penggembalaan secara berleluasa di padang ragut asli, tetapi tidak dipengaruhi oleh penggembalaan secara sederhana di padang ragut yang ditingkatkan.

**Kata kunci:** kualiti air, tumbuh-tumbuhan penutup bumi, spesis penceroboh, morfologi akar, sifat kimia tanah, sifat fizik tanah, penggembalaan secara berlebihan, penggembalaan secara sederhana.

## ACKNOWLEDGEMENTS

First and foremost, my gratitude is to God, the most gracious and merciful for his blessing. Writing this dissertation was not an accomplishment of my own. Hence, I would like to express some sincere words of thanks to the people that were indispensable in the realization of this work.

I owe the greatest thanks to Assoc. Prof. Dr. Ramdzani Abdullah, my supervisor, for his continued support, guidance and everything he has done for me over the last four years. I would like to thank him for the constructive and stimulating discussions. I am most grateful for his belief in me, because without it, this dissertation would never have become a reality. Dr. Ramdzani, it was a great honour to have had the opportunity to work with you and I would really like to continue the co-operation in the years ahead.

Furthermore, I would like to express my sincere thanks to all members of the supervisory committee: Assoc. Prof. Dr. Ahmad Husni Mohd. Hanif, Assoc. Prof. Dr. Ridzwan Abd. Halim and Assoc. Prof. Dr. Mohd Kamil Yusoff for their ideas, great insights and all help with this research. I am very lucky to have had such a strong committee to guide me along the way.

Special thanks go towards the Universiti Putra Malaysia for providing graduate research fellowship (GRF) to make this research possible. I express my appreciation to the staff of the Faculty of Environmental Studies, Haji Abdul Rashid Haron, Sujak Samad, Shamsuddin Johan, Nor Haizum Halmi, Suhana Muhammad and Noriyah



Muhammad for facilitating of lab and office works. I also express my sincere thanks to Sarimah Hashim and Mayudin Othman from Land Management Department of University Putra Malaysia for assistance with soil analysis.

My deepest appreciation is reserved for Professor Dr. Walter D. Willms from Agriculture and Agri-Food Canada, Imas S. Sitanggang from Bogor Agricultural University, Indonesia, and Mahmoud Danaei for their unconditional help and support in data analysis.

Most of all, to my wonderful wife Mahboubeh and lovely son Ahoora, who stuck by me and supported me through many times, I extend infinite love and appreciation. My special thanks to my family for instilling me the importance of education, their financial, encouragement, inspiration, concern and continuous moral support during this work. It was because of your unconditional support and understanding that I succeeded in passing the ups and downs in the past four, very turbulent years of my life.



I certify that a Thesis Examination Committee has met on 09 December 2010 to conduct the final examination of Majid Ajarlo on his thesis entitled “Impact of Cattle Grazing on Selected Environmental Variables in Pasture-based Livestock Production System” in accordance with the Universities and University Colleges Act 1971 and the constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

**Wan Nor Azmin B. Sulaiman, PhD**

Associate Professor  
Faculty of Environmental Studies  
Universiti Putra Malaysia  
(Chairman)

**Nik Muhamad Majid, PhD**

Professor  
Faculty of Forestry  
Universiti Putra Malaysia  
(Internal Examiner)

**Ahmad Ismail, PhD**

Professor  
Faculty of Science  
Universiti Putra Malaysia  
(Internal Examiner)

**Nanthi Sirangie Bolan, PhD**

Professor  
School of Natural and Built Environment  
University of South Australia  
(External Examiner)

---

**BUJANG BIN KIM HUAT, PhD**

Professor and Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 22 February 2011



This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

**Ramdzani Bin Abdullah, PhD**

Associate Professor  
Faculty of Environmental Studies  
Universiti Putra Malaysia  
(Chairman)

**Mohd Kamil Yusoff, PhD**

Associate Professor  
Faculty of Environmental Studies  
Universiti Putra Malaysia  
(Member)

**Mohd Ridzwan A. Halim, PhD**

Associate Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Member)

**Ahmad Husni Mohd. Hanif, PhD**

Associate Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Member)

---

**HASANAH MOHD GHAZALI, PhD**

Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 22 February 2011



## **Declaration**

I declare that the thesis is my original work except for quotations and citation, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

---

**MAJID AJORLO**

Date: 9 December 2010

## TABLE OF CONTENTS

	<b>Page</b>
<b>ABSTRACT</b>	ii
<b>ABSTRAK</b>	v
<b>ACKNOWLEDGEMENTS</b>	vii
<b>APPROVAL</b>	x
<b>DECLARATION</b>	xii
<b>LIST OF TABLES</b>	xviii
<b>LIST OF FIGURES</b>	xxii
<b>LIST OF ABBREVIATIONS</b>	xxvi
<b>CHAPTER</b>	
<b>1 INTRODUCTION</b>	
1.1 General	1
1.2 Problem statement	2
1.3 Research objectives	3
1.4 Significance of the study	4
1.5 Thesis structure	4
<b>2 LITERATURE REVIEW</b>	
2.1 Introduction	6
2.2 Impact of cattle grazing on surface water quality	6
2.2.1 Water quality indices	10
2.3 Impact of cattle grazing on soil properties	22
2.3.1 Impacts of grazing on soil chemical properties	27
2.3.2. Impact of grazing on the concentration of heavy metals	36
2.3.3 Impacts of grazing on soil physical properties	39
2.4 Impact of cattle grazing on pasture vegetation	46
2.4.1 Regrowth rate	47
2.4.2 Herbage mass yield	48
2.4.3 Plant height	52
2.4.4 Tiller density	54
2.4.5 Plant dead material and litter	56
2.5 Impact of cattle grazing on invasive species	57
2.5.1 Effects of species diversity and plant density on weed invasion	59
2.5.2 Effect of invasive species on pasture herbage yield	61
2.5.3 Effects of soil properties on weed invasion	62
2.6 Responses of root to grazing management	63
2.6.1 Rooting depth	65
2.6.2 Root mass	66
2.6.3 Root length	67
2.6.4 Specific root length	69
2.6.5 Root surface area	70
2.6.6 Root diameter	70
2.7 Summary	71



3	<b>MATERIALS AND METHODS</b>	
3.1	Introduction	73
3.2	Study area	73
	3.2.1 Geographic location	73
	3.2.2 Physiography	75
	3.2.3 Climate	75
	3.2.4 Soil	76
	3.2.5 Drainage system	77
	3.2.6 Pasture swards	79
3.3	Methodology	84
	3.3.1 Grazing treatments	84
	3.3.2 Assessment of grazing impact on surface water	85
	3.3.3 Assessment of grazing impact on soil properties	104
	3.3.4 Assessment of grazing impact on vegetation, invasive species and root characteristics	115
	3.3.7 Mitigation and amelioration of animal grazing impact	128
	3.3.9 Summary	128
4	<b>RESULTS AND DISCUSSION</b>	
4.1	Introduction	130
4.2	Impact of cattle grazing on surface water quality	130
	4.2.1 Variations of water quality parameters at sampling stations with different grazing treatments	130
	4.2.2 Variations of water quality parameters at sampling stations by climatic season	146
	4.2.3 Impact of grazing management and rainfall variation on water quality	144
	4.2.4 Impact of grazing management and rainfall variation interaction on water quality	158
	4.2.5 Water quality index of streams in the study areas	162
	4.2.6 Water quality index of streams based on the variation in rainfall	165
	4.2.7 Assessment of spatial and temporal variations in surface water quality using multivariate statistical techniques	169
	4.2.8 Mitigation and amelioration measures of grazing impacts on surface water quality	197
4.3	Impact of grazing on pasture soils properties	205
	4.3.1 Soil chemical properties	205
	4.3.2 Soil heavy metals concentration	217
	4.3.3 Soil physical properties	223
	4.3.4 Mitigation and amelioration of grazing impact on pasture soil	240
4.4	Impact of cattle grazing on pasture vegetation	247
	4.4.1 Harvest dates (sampling events)	247
	4.4.2 Responses of pasture vegetation to grazing management	249
	4.4.3 Impact of grazing management on invasive species	260
	4.4.4 Grazing effects on root morphology and distribution	269
	4.4.5 Mitigation and amelioration measures of cattle	297



grazing impact on pasture vegetation, invasive species and roots characteristics

5	<b>CONCLUSION AND RECOMMENDATIONS</b>	
5.1	Introduction	303
5.1.1	Impacts of cattle grazing on surface water quality	303
5.1.2	Impacts of cattle grazing on soil chemical properties	310
5.1.3	Impacts of cattle grazing on soil physical properties	311
5.1.4	Impacts of cattle grazing on pasture vegetation	315
5.1.5	Impacts of cattle grazing on invasive species	339
5.1.6	Impacts of cattle grazing on root morphology and distribution	316
5.2	Recommendations	319
	<b>REFERENCES</b>	322
	<b>APPENDIX</b>	349
	<b>BIODATA OF STUDENT</b>	367

