بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Effect of Soil Water Conservation Methods on Vegetative Growth and Yield of Sorghum (*Sorghum bicolor L. Moench*), Intercropped with Cow Pea (*Vigna ungcuilata L. Walp*) in Western Kordafan state.

أثر طرق حفظ رطوبة التربة علي النمو الخضري وإنتاج محصول الذرة المحملة مع محصول اللوبيا بولاية غرب كرد فان.

A thesis Submitted to Fulfill the Requirements for the Degree of Ph.D in (Agric.) crop production

By

Rahamtalla Mahgoub Elbuelgasim Musa

B.ScAgriculture University of Khartoum.(1994)

M.Sc Agriculture University of Khartoum (2006)

Supervisor

Dr. Samia Osman Yagoub

Co Supervisor

Dr. Mohammed Ahmed Bushara

July 2015

Dedication

To soule of my mother

To my father

To my Wife and Kids, Yosra, Mahgoub, Mohammed,Wafaa, Braha and Muslam

To my brother ELnazire

Acknowledgements

First of all praise is to ALLA for giving me strength and patience to complete this work successfully.

I would like to express my sincere thanks to Dr. Samia Osman Yagoub , under her supervision, I have received a lot off assistance and guidance without which this work could not have been a reality.

I wish to express my sincere thanks to my co supervisor Dr. Mohammed Ahamed Bushara for his excellent guidance and ad vice through the period of the study.

Special thanks to my family who encourage me with unlimited support.

Also warm thanks to staff members of Agronomy department, austaz Gafar for statistical analysis, Alazm and Dr. Moatasm for his encouragement.

The assistance of my colleagues in Salam University is greatly appreciated, warm thanks to the farmers who worked with me in the field Elnour and Malt in Babanousa Location. Abd Elases and Mohammed in Elfoula Location.Thanks to women who threshed the crop seeds Hlema, Elredia and Howi and the car driver Maki.The financial support through ministry of Higher Education and research (Tranining Department) is appreciated.

LIST OF CONFENTS

Title		page
ACKNOWLEDGMENTS		11
LIST OF CONTENTS		111
LIST OF TABLES		V11
ABSTRACT		XV11
ARABIC ABSTRACT		XV111
CHAPTER ONE INTRODUCTION		1
CHAPTER TWO LITERTAURE REVIEW		3
2.1	Sorghum	3
2.1.1	Latin name andcommon name	3
2.1.2	Crop description and climate	3
2.1.3	Cultural practices	4
2.14	Pest and diseases	4
2.1.5	Uses	5
2.1.6	Crop response to soil moisture	5
2.2	Cowpea	7
2.2.1	Crop description and climate	8
2.2.2	Crop establishment	9
2.2.3	Crop responses to soil moisture	10
2.3	Crop water stress and uses	11
2.4	Intercropping	13
2.5	Water conservation	18
2.6	Types of water harvesting techniques	21
2.7	Tillage	22
2.8	Traditional tools and implements	28
2.9	Terrace	30
2.10	Season and location	32
CHAPTER THREE MATERIALS AND METHODS		34
3.1	Experimental site	34
3.2	Land preparation	34

3.3	Source of seeds	35
3.4	Layout and experimental treatment	35
3.5	Seed rate	35
3.6	Weeds and insects control	35
3.2 Characters studied		35
3.2.1 Growth attributes		35
3.2.1.1	Plant height(cm)	36
3.2.1.2	Stem diameter	36
3.2.1.3	Leaf area	36
3.2.1.4	Seed /pod	36
3.2.1.5	Panicle length	36
3.3	Fresh weight	36
3.4	Dry weight	37
3.5	Seed yield	37
3.6	Final hay yield	37
3.7	Harvest index	37
3.8	Land equivalent ratio	37
3.9	Statistical analysis	38
CHAPTER FOUR RESULTS		39
4.1	Growth parameters (Elfoula)	39
4.1.1	Plant height	39
4.1.2	Stem diameter	42
4.1. 3	Leaf area	42
4.1.4	Fresh weight	47
4.1.5	Dry weight	47
4.2	Growth parameters (Babanousa)	52
4.1.2	plant height	52
4.2.2	Stem diameter	55
4.2.3	Leaf area	58
4.1.4	Fresh weight	61
4.2.5	Dry weight	64

4.3	Yield components(Elfoula)	67
4.3.1	Panicle length	67
4.3.2	Sorghum 1000 seed weight	69
4.3.3	Number of seeds/pod	71
4.3.4	Cowpea 100 seeds weight	72
4.4	Yield components (Babanousa	73
4..4.1.	Panicle length	73
4.4.2	Sorghum 1000seeds weight	74
4.4.3	Number of seeds/ pod	75
4.4.4	Cowpea 100 seeds weight	76

4.5	Location x season comparison	77
4.5.1	Panicle length	77
4.5.2	Sorghum 1000 seeds weight	77
4.5.3	Number of seeds/pod	78
4.5.4	Cow pea 100 seeds weight	79
4.6	The comparison between interaction of location and season on yield parameter	79
4.6.1	Final hay yield	79
4.6.2	Seeds yield	80
4.6.3	Harvest index	81
4.6	Yield parameter (Elfoula)	81
4.6.1	Final hay yield	81
4.6.2	Seed s yield	83
4.6.3	Harvest index	84
4.6.4	Final hay land equivalent ratio	85
4.6.5	Seed land equivalent ratio	86
4.7.	Yield parameter (babanosa)	87

4.7.1	Final hay yield	88
4.7.2	Seed yield	90
4.7.3	Harvest index	92
4.7.4	Final hay yield land equivalent ratio	93
4. 7.5	Seed land equivalent ratio	95
4.8	Comparison of interaction of season soil water conservation method and crop sowing methods (Elfoula)	96
4.8.1	Final hay yield	96
4.8.2	Seed yield	97
4.9	Comparison of interaction of season soil water conservation method and crop sowing methods (Babanousa)	98
4.9.1	Final hay yield	98
4.9.2	Seed yield	99
4.10	The effect of interaction between location , land preparation and crop sowing methods on vegetative growth	100
4.10.1	Plant height	100
4.10.2	Stem diameter	104
4.10.3	Leaf area	107
4.10.4	Fresh weight	110
4.10.5	Dry weight	113
4.11	The effect of interaction between location x land preparation methodsx crop sowing methods on yield parameter	117
4.11.1	Final hay yield	117
4.11.2	Seed yield	118
4.11.3	Harvest index	120
CHAPTER FIVE DISCUSSION		122
5.1	Growth parameter	122
5.2	Yield components	123
5.3	Interaction between location and season	123
5.4	Yield parameter	124
5.5	The effect of interaction between season, land preparation and crop sowing methods	125
5.6	The effect of interaction between season, land preparation and	125

	crop sowing methods on vegetative growth	
5.7	The effect of interaction between season, land preparation and crop sowing methods on yield parameter	126
5.8	Land equivalent ratio	127
CONCLUSIONS AND RECOMMENDATION 128		
REFRENCES 129		
APPENDIXES 149		

LIST OF TABLES

Table	Title	page
1a	The effect of soil water conservation methods on plant height of sorghum intercropped with cowpea in Elfoula season 2011/2012	40
1b	The effect of soil water conservation methods on plant height of sorghum intercropped with cowpea in Elfoula season 2012/2013	41
2a	The effect of soil water conservation methods on stem diameter of sorghum intercropped with cowpea in Elfoula season 2011/2012	43
2b	The effect of soil water conservation methods on stem diameter of sorghum intercropped with cowpea in Elfoula season 2012/2013	44
3a	The effect of soil water conservation methods on leaf area of sorghum intercropped with cowpea in Elfoula season 2011/2012	45
3b	The effect of soil water conservation methods on leaf area of sorghum intercropped with cowpea in Elfoula season	46

	2012/2013	
4a	The effect of soil water conservation methods on fresh weight of sorghum intercropped with cowpea in Elfoula season 2011/2012	48
4b	The effect of soil water conservation methods on fresh weight of sorghum intercropped with cowpea in Elfoula season 2012/2013	**49**
5a	The effect of soil water conservation methods on dry weight of sorghum intercropped with cowpea in Elfoula season 2011/2012	**50**
5b	The effect of soil water conservation methods on dry weight of sorghum intercropped with cowpea in Elfoula season 2012/2013	**51**
6a	The effect of soil water conservation methods on plant height of sorghum intercropped with cowpea in Babanousa season 2011/2012	**53**
6b	The effect of soil water conservation methods on plant height of sorghum intercropped with cowpea in Babanousa season 2012/2013	**54**
7a	The effect of soil water conservation methods on stem diameter of sorghum intercropped with cowpea in Babanousa season 2011/2012	**56**
7b	The effect of soil water conservation methods on stem diameter of sorghum intercropped with cowpea in Babanousa season 2012/2013	**57**
8a	The effect of soil water conservation methods on leaf area of sorghum intercropped with cowpea in Babanousa	**59**

	season 2011/2012	
8b	The effect of soil water conservation methods on leaf area of sorghum intercropped with cowpea in Babanousa season 2012/2013	**60**
9a	The effect of soil water conservation methods on fresh weight of sorghum intercropped with cowpea in Babanousa season 2011/2012	**62**
9b	The effect of soil water conservation methods on fresh weight of sorghum intercropped with cowpea in Babanousa season 2012/2013	**63**
10a	The effect of soil water conservation methods on dry weight of sorghum intercropped with cowpea in Babanousa season 2011/2012	**65**
10b	The effect of soil water conservation methods on dry weight of sorghum intercropped with cowpea in Babanousa season 2012/2013	**66**
11	The effect of soil water conservation methods on panicle length of sorghum intercropped with cowpea in Elfoula season 2011/12 and 2012/13	**68**
12	The effect of soil water conservation methods on 1000s seed weight of sorghum intercropped with cowpea in Elfoula season 2011/12 and 2012/13	**70**
13	The effect of soil water conservation methods on number of seed /pod of sorghum intercropped with cowpea in Elfoula season 2011/12 and 2012/13	**71**
14	The effect of soil water conservation methods on 100s seed weight of cowpea intercropped with sorghum in	**72**

	Elfoula season 2011/12 and 2012/13	
15	The effect of soil water conservation methods on panicle length of sorghum intercropped with cowpea in Babanouusa season 2011/12 and 2012/13	**73**
16	The effect of soil water conservation methods on 1000s seed weight of sorghum intercropped with cowpea in Elfoula season 2011/12 and 2012/13	**74**
17	The effect of soil water conservation methods on number of seed /pod of sorghum intercropped with cowpea in Babanousa season 2011/12 and 2012/13	**75**
18	The effect of soil water conservation methods on 100s seeds weight of sorghum intercropped with cowpea in Babanousa season 2011/12 and 2012/13	**76**
19	The effect of location x season on panicle length of sorghum intercropped with cowppea	**77**
20	The effect of location x season on 1000s seeds weight of sorghum intercropped with cowpea	**78**
21	The effect of location x season on number of seed/pod of cowpea intercropped with sorghum	**78**
22	The effect of location x seasons on 100s seed weight of cowpea intercrop with sorghum	**78**
23	The effect of location x seasons on final hat yield	**80**
24	The effect of location x seasons on seed yield	**80**
25	The effect of location x seasons on harvesting index	**81**
26a	The effect of soil water conservation methods on final hay yield of sorghum intercrop with cowpea Elfoula season 2011/12	**82**

26b	The effect of soil water conservation methods on final hay yield of sorghum intercrop with cowpea Elfoula season 2011/13	**82**
27a	The effect of soil water conservation methods on seed yield of sorghum intercrop with cowpea Elfoula season 2011/12	**83**
27b	The effect of soil water conservation methods on seed yield of sorghum intercrop with cowpea Elfoula season 2012/13	**84**
28a	The effect of soil water conservation methods on harvesting index of sorghum intercrop with cowpea Elfoula season 2011/12	**85**
28b	The effect of soil water conservation methods on harvesting index of sorghum intercrop with cowpea Elfoula season 2011/13	**85**
29	The effect of soil water conservation methods on final hay land equivalent ratio in Elfoula season 2011/and 2012/2013	**86**
30	The effect of soil water conservation methods on seed land equivalent ratio in Elfoula season 2011/and 2012/2013	**87**
31	The effect of soil water conservation methods on final hay yield in Babanousa season 2011/and 2012/2013	**89**
32	The effect of soil water conservation methods on seed yield in Babanousa season 2011/and 2012/2013	**91**
33a	The effect of soil water conservation methods on harvesting index in Babanousa season 2011/2012	**92**
33b	The effect of soil water conservation methods harvesting	**93**

	index in Babanousa season 2012/20133on	
34a	The effect of soil water conservation methods on final hay land equivalent ratio in Babanousa season 2011/2012	**94**
34b	The effect of soil water conservation methods on final hay land equivalent ratio in Babanousa season 2012/2013	**94**
35a	The effect of soil water conservation methods on final hay land equivalent ratio in Babanousa season 2012/2013	**95**
35b	The effect of soil water conservation methods on final hay land equivalent ratio in Babanousa season 2012/13	**96**
36	The interaction between season and soil water conservation methods on hay yield in Elfoula	**97**
37	The interaction between season and soil water conservation methods on seed yield in Elfoula	**98**
38	The interaction between season and soil water conservation methods on hay yield in Babanousa	**99**
39	The interaction between season and soil water conservation methods on seed yield in Babanousa	**100**
40a	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant height 30 days after sowing season 2011/2012	**101**
40b	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant height 45 days after sowing season 2011/2012	**101**
40c	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant height 60 days after sowing season 2011/2012	**102**
40d	Comparison of location , soil water conservation and crop	**102**

	sowing methods on sorghum and cowpea plant height 30 days after sowing season 2012/2013	
40e	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant height 45 days after sowing season 2012/2013	**103**
40f	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant height 60 days after sowing season 2012/2013	**103**
41a	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant stem diameter 30 days after sowing season 2011/2012	**104**
41b	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant stem diameter 45 days after sowing season 2011/2012	**105**
41c	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant stem diameter 60 days after sowing season 2011/2012	**105**
41d	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant stem diameter 30 days after sowing season 2012/2013	**106**
41e	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant stem diameter 45days after sowing season 2012/2013	**106**
41f	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant stem diameter 60 days after sowing season 2012/2013	**107**
42a	Comparison of location , soil water conservation and crop	**108**

	sowing methods on sorghum and cowpea plant leaf area index 30 days after sowing season 2011/2012	
42b	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant leaf area index 45 days after sowing season 2011/2012	**108**
42c	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant leaf area index 60days after sowing season 2011/2012	**109**
42d	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant leaf area index 30 days after sowing season 2012/2013	**109**
42e	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant leaf area index 45 days after sowing season 2012/2013	**110**
42f	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant leaf area index60 days after sowing season 2012/2013	**110**
43a	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant fresh weight 30 days after sowing season 2011/2012	**111**
43b	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant fresh weight 45 days after sowing season 2011/2012	**111**
43c	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant fresh weight60 days after sowing season 2011/2012	**112**
43d	Comparison of location , soil water conservation and crop	**112**

	sowing methods on sorghum and cowpea plant fresh weight 30 days after sowing season 2012/2013	
43e	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant fresh weight 45 days after sowing season 2012/2013	**113**
43f	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant fresh weight 60 days after sowing season 2012/2013	**113**
44a	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant dry weight 30 days after sowing season 2011/2012	**114**
44b	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant dry weight 45days after sowing season 2011/2012	**114**
44c	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant dry weight 60 days after sowing season 2011/2012	**115**
44d	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant dry weight 30 days after sowing season 2012/2013	**115**
44e	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant dry weight 45 days after sowing season 2012/2013	**116**
44f	Comparison of location , soil water conservation and crop sowing methods on sorghum and cowpea plant dry weight 60 days after sowing season 2012/2013	**116**
45a	Comparison of final hay yield (t/ha) Elfoula and	**117**

	Babanousa 2011/2012 on interaction between location .treatment and crop sowing methods	
45b	Comparison of final hay yield (t/ha) Elfoula and Babanousa 2012/2013 on interaction between location .treatment and crop sowing methods	**118**
46a	Comparison of seed yield (t/ha) Elfoula and Babanousa 2011/2012 on interaction between location .treatment and crop sowing methods	119
46b	Comparison of seed yield (t/ha) Elfoula and Babanousa 2012/2013 on interaction between location .treatment and crop sowing methods	119
47a	Comparison of harvesting index Elfoula and Babanousa 2011/2012 on interaction between location .treatment and crop sowing methods	120
47b	Comparison of harvesting index Elfoula and Babanousa 2012/2013 on interaction between location .treatment and crop sowing methods	121

Abstract

Field experiments were conducted in two locations (Elfoula and Babanousa), Western Kordofan state seasons 2011/ 12 and 2012/ 13, to determine the effect of soil water conservations methods on vegetative growth of sorghum crop intercropped with cowpea.The experimental design was randomized complete plots design with three replications. The main plots were assigned forhand hoe (main local method of plough used) (L_1) and hand hoe with terrace L_2, animal plough L_3 and animal plough with terrace L_4. The crop sowing methods waslaid in sub plots as follows:S_1 Sorghum mono crop, S_2 Sorghum intercrop,C_1 Cowpea intercrop, C_2 Cowpea mono crop.

Generally the soil preparation with animal traction and terrace (L_4) showed the highest plant height, stem diameter, leaf area index, and dry weight products followed by soil prepared with hand hoe and terrace for two locations and two seasons.

The effect of methods of land preparation on soil moisture conservation and its effectiveness on yield components of sorghum intercropped with cowpea for two locations.The resultsshowed that L4 (animal traction plough with terrace and mono crop sowing methods) obtained high yield compound within location and seasons.Location (Lo2, Se1), Babanousa location season 2011/ 12 showed high yield compound than other treatments.For the two locations and seasons, the result was that L4(animal traction with terrace and monocrop methods) showed high yield. Also the results showed that the vegetative growth and yield components of sorghum intercropped with cowpea was varied within location and seasons.

الخلاصة:

أجريت التجارب الحقلية في موقعين (الفولة وبابنوسة)بولاية غرب كردفان للموسمين 12/2011 و 2012 / 13، لتحديد تأثير حفظ مياه التربة على النمو الخضري لمحصول الذرةمحمل مع محصول اللوبيا،وتم تنفيذ التجربة بتصميم القطع المنشقةعلي ثلاث مكررات. تمتحديد القطع الرئيسية لطرق تحضير الأرضالجراية (L1) والجراية مع الترس (L2)، المحراث (L3) والمحراث مع الترس (L4). بذر المحاصيل وضعت في القطع الفرعية على النحو التالي: S1 الذرة محصول أحادية، S2 الذرة محملة، C1 اللوبيا محملة، C2 محصول اللوبيا أحادية. عموما أدي إعداد التربة بالمحراث والترس (L4) أظهرت أعلى ارتفاع للنبات، قطر الساق، مساحة الورقة، والوزن المنتجات الجافة تليها الجراية مع الترس ،

تأثير أساليب إعداد الأرض على الحفاظ على رطوبة التربة وفوائده على مكونات محصول الذرة مع اللوبيا للموقعين. وأظهرت النتائج أن L4 (المحراث مع الترس وأحادية بذر المحاصيل) الحصول على ارتفاع مجمع العائد داخل الموقع والمواسم .أظهرت التجربة إن هنالك تباينفي المواقع والمواسم، وكانت النتيجة أن L4 (المحراث مع الترس وذات المحصول الواحد) أظهرت ارتفاع العائد.

أظهر موقع (LO2، SE1) موقعبابنوسة موسم 2012/2011 مكونات عالية الغلة من العلاجات الأخرى. كما أظهرت النتائج أن النمو ومكوناته النباتية من الذرة مع اللوبيا قد تختلف داخل الموقع والمواسم.