Dedications

To my husband and family,

To Kuku Dairy producers

and those who suffered From Brucellosis

I dedicate this work.

Khansaa
Acknowledgements

First, Thank God who gave me the patience, ability and strength to complete this work.

I was told before I came to work with Prof Mohamed Hashim Awad and Prof Babikir Alhaj that they did not tolerate” tomfoolery." Accordingly, I must convey gratitude to my supervisors for years of academic guidance, and the occasional "tomfoolery"-correction. For patient and valuable recommendations throughout this work.

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Most importantly, my family has all sacrificed so that I could be a student:

My mother, husband, Anfal, Amel, Sami, Amin, Rawan Elnour and Aam. I can never repay that debt.
ABSTRACT

The objective of this research is to quantify the impact of Brucellosis on Kuku Dairy scheme. Ecozoo model with introduction of some modifications was used as analytical framework. It provides the information needed to analyze the epidemiology of the disease in both animals and humans as well as the economic analysis. Epidemiological data required were obtained from primary sources. These include two seroprevalence surveys for cattle, personal communications were also used as a source of primary data.

Two field surveys (including seroprevalence and socioeconomic surveys) were conducted during the period Jan- June 2004. The Humans Brucellosis survey included 176 Volunteers from the population at risk. In the Bovine Brucellosis survey the sample design was based on two stages random sample design. In the first stage, holdings (the primary statistical units) were identified. Then the individual Animals (the Secondary Statistical units) were selected. The size of the primary Statistical units was calculated as 30.1 with $\alpha = 0.05$ and desired accuracy of (10). The number of animals examined was 574.

The laboratory diagnosis relied mainly on serological tests namely Rose–Bengal Test (RBT) as screening test and Competitive Enzyme linked Immuno- Sorbent Assay (cELISA) as confirmatory test. Tube agglutination test (TAT) was used as a routine test.
According to the confirmatory test: the herd prevalence rate is 90%, individual animal prevalence rate 24.9% and average within herd prevalence rate 24.5% (Sd 15.7 CI 4.088 at 95%). Based on c-Elisa human prevalence rate is 11.3% considering the seropositivity and 2.8% considering active brucella infection. Based on prevalence rates estimates on human parameters was found to be 18 active infected person in the baseline year and the infected cattle are 1508 head. These parameters were introduced into Ecozoo model. Data for DALYs calculation were obtained from primary sources as well as secondary sources.

Based on the epidemiological and economic data the total cost of the disease in both dairy and health sectors was found to be 67126953.8 SD out of which 66910503.8 SD was the cost of the dairy sector and 216450SD was the cost of health sector. Accordingly, the dairy sector Shouldered 99.76% of the cost, while the health sector Shouldered 0.33% of Brucellosis cost in the base line year.

The burden of the disease was measured in DALYs. In the baseline year 18 persons were infected with Brucellosis. If we considered Brucellosis associated with level 0.1-disability weight, every infected person will loose 0.392659 year of his healthy life as a result of the infection. The total infected people will loose 7.067862 years of their healthy life. If the disease associated with level 0.2 disability weight, every infected person will loose 0.785318 years and the whole infected people will loose 14.13572 years of their healthy life.
Evolution of the disease over 11 years was investigated in two scenarios. In scenario 1 the total animal population was left to grow at the normal rates. In this case the number of seropositive animals will increase with growth rate of 103.2% followed by the increase in number of actively infected humans with growth rate of 27.8%.

The total cost of the disease in both dairy and health sectors were found to be 1022123020SD (745547286 SD in PV) equivalent to 4088492.08 US$ over the 11 years.

The total loss of healthy years over the 11 years will account to 59.7 years (0.1 DW). And 119.4 years (0.2 DW).

In Scenario 11 the total number of animals was held constant. In this case the number of seropositive animals will increase during the 11 years with growth rate of 258.1% Followed by the increase in number of actively infected humans with growth rate of 133%. The total cost of the disease in both dairy and health sectors was found to be 1414827570SD (101505075 in PV) equivalent to 5655170.142US$ over the 11 years.

The total loss of healthy years over the 11 years will account to 89.1 years (0.1 DW). And 178.3 years (0.2 DW).

Most of the producers (80%) are well informed about the disease and its zoonotic nature, (53%) are well acquainted with the economic importance of the disease. All of them Support the idea of disease control.

The study confirm the endimicity of the scheme with both human and bovine Brucellosis.and prove the economic loss due to disease both financial and its burden on human heath.
The study recommends intervention to control the disease. Adoption of Whole herd Vaccination policy was recommended. Simulation of different intervention strategies to analyze the cost and benefits will help policy makers in setting up their priorities.

الخلاصة

استهدفت الدراسة تقدير الخسائر الناتجة عن تفشى مرض البروسيلوزس بمشروع ألبان كوكو مع إجراء بعض التعديلات كأداة للتحليل. تم الحصول على البيانات المطلوبة من مصادرها الأولية والثانية. للحصول على البيانات الأولية تم إجراء مسحين حقيقيين لجمع بيانات عن بر وسيلانا الإنسان وأخر عن بر وسيلة الأبقار. أيضا تم استخدام أسلوب المقابلة الشخصية مع المنتجين و الخبراء لجمع البيانات الأولية.

تم إجراء مسح بر وسيلة الإنسان في الفترة ما بين ينائر إلى يونيو 2004 حيث جمعت عينات للدم من 176 مترع بالإضافة إلى البيانات المطلوبة.

اعتمد التشخيص المعملي على اختبارات المصل بالتحديد اختبار الروز بنجال ككشف مسحي واختبار c-ELISA كاختبار تأكيدي. أخذت العينات أيضا لاختبار تواتني TAT يجرى بالسودان.

لتقدير عقباء المرض على الإنسان تم استخدام مؤشر غير نفدي (زمني) يعرف بسنوات التعطيل المعدلة.

بالنسبة لبر وسيلة الأبقار تم اختيار العينة على مرحلتين ، في المرحلة الأولى تم اختيار الحيازات ( القطعان) عشوائيا. في المرحلة الثانية تم اختيار الوحدات الإحصائية (الحيوانات).

استهدفت الدراسة كل الأبقار البالغة. بلغ عدد الحيازات المختارة 30 حيزة بينما بلغ عدد الأبقار 574. حيث تم اخذ العينات وفحصها بواسطة اختبار الروز بنغال و c-ELISA.
فيما يتعلق بانتشار المرض توصلت الدراسة إلى النتائج التالية:

بلغ معدل انتشار المرض في الإنسان 11.3% بناءً على اختبار المصل و2.8% بناءً على الإصابة الحقيقية.

بالنسبة للأبقار، بلغ معدل انتشار المرض في القطعان 90%， معدل الانتشار بين الأبقار 24.9% ونسبة معدل الانتشار داخل القطيع 24.5%.

بناءً على هذه المعدلات، بلغ تقدير عدد الأشخاص المصابة في السنة الأساس 18 شخصًا وعدد الأبقار المصابة 1508. بلغ تقدير الخسائر الناجمة عن المرض 67126953.8 دينار (سبعة وستون مليونًا ومانهًا وعشرون ألفًا وتسعمائة ثلاث خمسون دينار). من هذة الخسائر، بلغت الخسائر في قطاع الصحة 216450 (مادتان وأربعة عشر ألفًا وأربعمائة خمسون دينار). عليه فإن قطاع الألبان يتحمل 99.76% من تكلفة المرض بينما يتحمل قطاع الصحة 0.33% من التكلفة.

فيما يتعلق بالعبء الصحي على الإنسان، توصلت الدراسة إلى أن الفرد المصاب يفقد من سنوات عمره المعافاة إذا ارتبط المرض بوزن 0.1 سنة 0.785318 والذي يبلغ عدد سنوات العمر المعافاة التي يفقدها المصابون في السنة الأولى 7.067862 سنة و14.13572 سنة في السنة الثانية.

بحثت الدراسة تطور المرض خلال 11 سنة من خلال سيناريوهين. في السيناريو الأول، ترك العدد الكلي للحيوانات ينمو بوفق المعدلات الجارية. في هذه الحالة، فإن عدد الحيوانات المصابة سوف ينمو بمعدل 103.2% وينمو عدد الأفراد المصابة بمعدل 27.8% وتكون تكلفة المرض الكلية في خلال إحدى عشر سنة (2004-2014) 1022123020 دينار 45547286 بدونة بالقيمة الحالية. ما يعادل 4647492.08 دولار.

بلغ عدد سنوات العمر المعافاة المفروضة إحدى عشر سنة 59.7% سنة 0.1 و119.4 سنة بوزن 0.2.

أجري السيناريو الثاني بفرض ثبات العدد الكلي للحيوانات. في هذه الحالة، فإن عدد الحيوانات المصابة سوف يزيد بمعدل 1.258% في خلال إحدى عشر سنة بينما يزيد عدد الأفراد
المصابين أصابه فعليه 133% . تبلغ التكلفة الكلية للمرض 14114827570 دينار

دينار بالقيمة الحالي. ما يعادل 142101505075 دولار.

يقدر الفقد الكلي لسنوات العمر المعافاة ب 89.1 سنة بوزن 0.1 و 178.3 بالوزن 0.2 . توصلت

الدراسة الى أن معظم المنتجين (80%) لديهم العلم الكافي بالمرض وطبيعته المعدية للإنسان. وأن

(53%) منهم يدركون أهميته الاقتصادية. أكدت الدراسة استيGAN المرشح بالمشروع وأثبتت

الخسائر الناجمة عنه. كما أوضحت تطور المرض والخسائر الناتجة عن ذلك عند عدم السيطرة عليه

في خلال إحدى عشر سنة. أوصت الدراسة بالتدخل للسيطرة على المرض في الحيوان وذلك بإتباع

سياسة التطعيم الكلي للقطع ثم تطعيم العجول سنويا والحيوانات البالغة كل سنتين لمدة عشر سنوات

ثم إتباع سياسة الفحص وذبح الحيوانات الموجبة. وذلك بعد مضايحة الاستراتيجية المختارة

بمعدلات مختلفة لكفاءة المصل لتحقيق نسبة التكاليف والمنافع مما يساعد متخذي القرار في اختيار

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LIST OF ABBREVIATIONS

ACAPP Arab Company for Agriculture production and processing
ASA Applied science and analysis
BBAT Buffered Brucella antigen tests
BEP Brucellosis Eradication Program
BTB Bovine tuberculosis
Cc Conjugate control

c-ELISA. Competitive Enzyme Linked Immuno- sorbent Assay.
CDC The Centers for Disease Control and Prevention
CNS Central Nervous System
CF Complement fixation
DALYs. Disability-adjusted life years
Defra Department for Environmental, Food and Rural Affairs

DW Disability weight
DBMD Division of Bacterial and Mycotic Diseases
FAO Food and Agriculture Organization
GATT General agreement on Trade and Tariff
GU Genitourinary
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<td>HR P</td>
<td>Horse-radish peroxidase</td>
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<td>IELISA</td>
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<td>ICFTU</td>
<td>International Complement Fixation Unit</td>
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<td>IM</td>
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<td>Livestock development planning system</td>
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<td>OIE</td>
<td>Office International des Epizooties</td>
</tr>
<tr>
<td>OIEISS</td>
<td>OIE International Standard System</td>
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<tr>
<td>PBS</td>
<td>Phosphate buffer saline</td>
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<tr>
<td>PCR</td>
<td>Polymerase chain reaction</td>
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<tr>
<td>PI</td>
<td>Percentage inhibition</td>
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<tr>
<td>PO</td>
<td>Per Oss</td>
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<td>PP</td>
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RBT  Rose –Bengal Test
SAT  Serum agglutination test
S-LPS Smooth Lipopoly Saccaride
ST streptomycin
STA Standard tube agglutination
TAT Tube Agglutination Test
TMP-SMZ trimethoprim/sulfamethoxazole
WHO World Health Organization
WTO World Trade Organization

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Dedications

To my husband and family,
To Kuku Dairy producers

and those who suffered From Brucellosis

I dedicate this work.

Khansaa

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First, Thank God who gave me the patience, ability and strength to complete this work.

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Most importantly, my family has all sacrificed so that I could be a student:

My mother, husband, Anfal, Amel, Sami, Amin, Rawan Elnour and Aam. I can never repay that debt.

ABSTRACT

The objective of this research is to quantify the impact of Brucellosis on Kuku Dairy scheme. Ecozoo model with introduction of some modifications was used as analytical framework. It provides the information needed to analyze the epidemiology of the disease in both animals and humans as well
as the economic analysis. Epidemiological data required were obtained from primary sources. These include two seroprevalence surveys for cattle, personal communications were also used as a source of primary data.

Two field surveys (including seroprevalence and socioeconomic surveys) were conducted during the period Jan- June 2004. The Humans Brucellosis survey included 176 Volunteers from the population at risk. In the Bovine Brucellosis survey the sample design was based on two stages random sample design. In the first stage, holdings (the primary statistical units) were identified. Then the individual Animals (the Secondary Statistical units) were selected. The size of the primary Statistical units was calculated as 30.1 with $\alpha =0.05$ and desired accuracy of (10). The number of animals examined was 574.

The laboratory diagnosis relied mainly on serological tests namely Rose–Bengal Test (RBT) as screening test and Competitive Enzyme linked Immuno- Sorbent Assay (c-ELISA) as confirmatory test. Tube agglutination test (TAT) was used as a routine test.

According to the confirmatory test: the herd prevalence rate is 90%, individual animal prevalence rate 24.9% and average within herd prevalence rate 24.5% (Sd 15.7 CI 4.088 at 95%). Based on c-Elisa human prevalence rate is 11.3% considering the seropositivity and 2.8% considering active brucella infection. Based on prevalence rates estimates on human parameters was found to be 18 active infected person in the baseline year and the infected cattle are 1508 head. These parameters were introduced into Ecozoo model. Data for DALYs calculation were obtained from primary sources as well as secondary sources.
Based on the epidemiological and economic data the total cost of the disease in both dairy and health sectors was found to be 65833570 SD out of which 65617120 SD was the cost of the dairy sector and 216450 SD was the cost of health sector. Accordingly, the dairy sector Shouldered 99.97 % of the cost, while the health sector Shouldered 0.03% of Brucellosis cost in the base line year.

The burden of the disease was measured in DALYs. In the baseline year 18 persons were infected with Brucellosis. If we considered Brucellosis associated with level 0.1-disability weight, every infected person will lose 0.392659 year of his healthy life as a result of the infection. The total infected people will loose 7.067862 years of their healthy life. If the disease associated with level 0.2 disability weight, every infected person will loose 0.785318 years and the whole infected people will loose 14.13572 years of their healthy life.

Evolution of the disease was investigated in two scenarios. In scenario 1 the total animal population was left to grow at the normal rates. In this case the number of seropositive animals will increase with growth rate of 1.574 followed by the increase in number of actively infected humans with growth rate of 1.875.

The total cost of the disease in both dairy and health sectors were found to be 936445610SD (\textbf{665340905.8} SD in PV) over the 10 years, out of which 934974941SD (664219621.8SD in PV) was the cost of the dairy sector and 1610142 SD (1121284 SD in PV) was the cost of health sector.

The total loss of healthy years over the 10 years will account to 52.61631 years (0.1 DW). And 105.2326 years (0.2 DW).
In Scenario 11 the total number of animals was held constant. In this case the number of seropositive animals will increase during the 10 years with growth rate of 2.27. Followed by the increase in number of actively infected humans with growth rate of 3.667. The total cost of the disease in both dairy and health sectors was found to be \(1321723709\) SD (\(912709172\) SD in PV) over the 10 years, out of which \(1319199296\) SD (\(911003344\) SD PV) was the cost of the dairy sector and \(2524413\) SD (\(1705828\) SD in PV) was the cost of health sector.

The total loss of healthy years over the 10 years will account to \(82.06573\) years (0.1 DW). And \(164.1315\) years (0.2 DW).

Most of the producers (80%) are well informed about the disease and its zoonotic nature, (53%) are well acquainted with the economic importance of the disease. All of them Support the idea of disease control.

The study confirm the endimicity of the scheme with both human and bovine Brucellosis. and prove the economic loss due to disease both financial and its burden on human heath.

The study recommends intervention to control the disease. Adoption of Whole herd Vaccination policy was recommended. Simulation of different intervention strategies to analyze the cost and benefits will help policy makers in setting up their priorities.

الخلاصة

استهدفت الدراسة تقدير الخسائر الناتجة عن تفشي مرض البروسيلووز بمشروع ألبان كوكو.
استخدمت الدراسة نموذج الEcozoo مع إجراء بعض التعديلات كأداة للتحليل. تم الحصول على البيانات المطلوبة من مصادرها الأولية والثانوية. للحصول على البيانات الأولية تم إجراء مسحين حقلين لجمع بيانات عن بر وسيلة الإنسان وأخرى عن بر وسيلة الأبقار. أيضا تم استخدام أساليب المقابلة الشخصية مع المنتجين والخبراء لجمع البيانات الأولية.

تم إجراء مسح بر وسيلة الإنسان في الفترة ما بين يناير إلى يونيو 2004 حيث جمعت عينات للماء من 176 مبارة بالإضافة إلى البيانات المطلوبة.

اعتمد التشخيص العملي على اختبارات المصل بالتحديد اختبار الروز بنغال ككشف مسحي واختبار اختبار روتيني c-ELISA كاختبار تأكيدي. أخذت العينات أيضا لاختبارات TAT.

للتزويج عبء المرض على الإنسان تم استخدام مؤشر غير نقي (زمني) يعرف بسنوات التعطيل المعدلة.

بالمثلية لبر وسيلة الأبقار تم اختيار العينة على مرحلتين، في المرحلة الأولى تم اختيار الحيازات (القطعان) عشوائياً. في المرحلة الثانية تم اختيار الوحدات الإحصائية (الحيوانات). استهدفت الدراسة كل الأبقار البالغة. بلغ عدد الحيازات المختارة 30 حيزة بينما بلغ عدد الأبقار 574. حيث تم اخذ العينات وفحصها بواسطة اختبار الروز بنغال و c-ELISA.

فيما يتعلق بالانتشار المرض توصلت الدراسة إلى النتائج التالية:

بلغ معدل انتشار المرض في الإنسان 11.3% بناء على إيجابية اختبار المصل و2.8% بناء على الإصابة الحقيقية.

بالنسبة للأبقار، بلغ معدل انتشار المرض في القطعان 90%، معدل الانتشار بين الأبقار و24.9% بمعنى متوسط معدل الانتشار داخل القطاع 24.5%.

بناء على هذه المعدلات بلغ تقدير عدد الأشخاص المصابين في سنة الأساس 18 شخصا وعدد الأبقار المصابة 1508. بلغ تقدير الخسائر الناجمة عن المرض بـ67126953.8 دينار (سبعة وستون مليونا وثمانون ألفا مائة سنتان وعشرون ألفا وثمانون ألفا). منها 66910503.8 دينار (ستة وستون مليونا وستمائة وثمانية ألفا وخمسة وأربعة آلافا وسنتان وثلاثي وثلاثي دينار) خسائر قطاع الألبان. بينما بلغت الخسائر في قطاع الصحة 216450 ( مائتان وأربعة عشر ألفا وأربعمائه وثلاثية دينار).
وخمسمائة دينار. عليه فإن قطاع الألبان يتحمل 99.76% من تكالفة المرض بينما يتحمل قطاع الصحة 0.33% من التكلفة.

فيما يتعلق بالعبء الصحي على الإنسان، توصلت الدراسة إلى أن الفرد المصاب يفقد 0.392659 سنة من سنوات عمره المعافاة إذا ارتبط المرض بوزن 0.1 و 0.785318 سنة إذا ارتبط المرض بالوزن 0.2، وعليه يبلغ عدد سنوات العمر المعافاة التي يفقدها المصابون في الحالة الأولى 99.76% و 14.13572 سنة في الحالة الثانية.

بحثت الدراسة تطور المرض خلال 11 سنة من خلال سيناريوين: في السيناريو الأول ترك العدد الكلي للحيوانات بنمو وفق معدلات الجارية. في هذه الحالة فإن عدد الحيوانات المصابة سوف ينمو بمعدل 103.2% و ينمو عدد الأفراد المصابين بمعدل 27.8% و تتكون تكالفة المرض الكلية في خلال إحدى عشر سنة (2004-2014) 1022123020 دينار 745547286 دينار بالقيمة الحالية. ما يعادل 4088492.08 دولار.

بلغ عدد سنوات العمر المعافاة المفقودة إحدى عشر سنة 59.7 سنة بوزن 0.1 و 119.4 سنة بوزن 0.2.

أجرى السيناريو الثاني بافتراض ثبات العدد الكلي للحيوانات. في هذه الحالة فإن عدد الحيوانات المصابية سوف يزداد بمعدل 1.258% في خلال إحدى عشر سنة بينما يزيد عدد الأفراد المصابين أصابه فعليه 133.1258%.

تبلغ التكالفة الكلية للمرض 1414927570 دينار. ما يعادل 5655170.142 دولار SD101505075

يشير التقرير الكلي للسنوات العمرة المعافاة ب 89.1 سنة بوزن 0.1 و 178.3 بالوزن 0.2. توصلت الدراسة إلى أن معظم المنتجين (80%) لديهم العلم الكافي بالمرض وطبقته المعدية للإنسان. وأن (53%) منهم يدركون أهميه الاقتصادية. أكدت الدراسة استبان المرض بالمشروع وأثبتت الخسائر الناجمة عنه. كما أوضحت تطور المرض والخسائر الناتجة عن ذلك عند عدم السيطرة عليه في خلال إحدى عشر سنة. أوصت الدراسة بالتدخل للسيطرة على المرض في الحيوان وذلك بإتباع سياسة التطعيم الكلي للقطاع ثم تطعيم الجرذان سنويا والحيوانات البالغة كل سنتين لمدة عشر سنوات ثم إتباع سياسة الفحص وذبح الحيوانات الموجبة. وذلك بعد مضاعفة الاستراتيجية المختارة.
بمعدلات مختلفة للفعَّالة المصل لتحديد نسبه التكاليف والمنافع مما يساعد متخذي القرار في اختيار البديل المناسب.
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\[ \frac{1}{n} = \frac{1}{nX} + \frac{1}{N} \]  \hspace{1cm} (1)

\[ Z \cdot st(p) = Z \{ (P.q/n) \cdot (N-n)/N \}^{1/2} \]  \hspace{1cm} (2)

\[ \alpha_{c(\text{effective})} = \alpha_{c(\text{baseline})} \cdot (1 - \eta) \cdot \left( \frac{Y}{X+Y} \right) \]  \hspace{1cm} (3)

\[ \text{Incidence}_{\text{cattle}} = \gamma_{c} \beta_{c}XY \]  \hspace{1cm} (4)

\[ \frac{dx}{dt} = \alpha_{c} (X+Y)(1-(\eta \cdot (Y/(X+Y)))) - \mu_{c}X - \gamma_{c}\beta_{c}XY \]  \hspace{1cm} (5)
\[
\begin{align*}
\frac{dY}{dt} &= \gamma c \beta c \ XY - \mu c X \quad (6) \\
\frac{dA}{dt} &= \nu h (A+B+C) + \lambda C - (\gamma c \beta c h AY) - \mu h A \quad (7) \\
\frac{dB}{dt} &= (P \gamma c \beta c h AY) - \kappa B - \mu h B \quad (8) \\
\frac{dC}{dt} &= (1-P) \gamma c \beta c h AY + \kappa B - \lambda C - \mu h C \quad (9) \\
YLD &= DW \left\{ \frac{Kc e^{ra}}{(r + \beta)} \left\{ (L + a) - (L - a) - e^{(r + \beta) a} \right\} + \frac{1}{1-K} \left\{ 1 - e^{-r L} \right\} \right\} \\
&\quad (r + \beta)^2 r
\end{align*}
\]
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<td>Fig. 7b</td>
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Fig. 8b  Change in the number of susceptible, infected and Immune humans in Kuku scheme with constant animal population

LIST OF ABBREVIATIONS

ACAPP  Arab Company for Agriculture production and processing
ASA    Applied science and analysis
BBAT   Buffered Brucella antigenic tests
BEP    Brucellosis Eradication Program
BTB    Bovine tuberculosis
Cc      Conjugate control

CELISA. Competitive Enzyme Linked Immuno- sorbent Assay.
CDC    The Centers for Disease Control and Prevention
CNS    Central Nervous System
CF     Complement fixation
<table>
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<tr>
<td>DALYs.</td>
<td>Disability-adjusted life years</td>
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<tr>
<td>Defra</td>
<td>Department for Environmental, Food and Rural Affairs</td>
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<td>DW</td>
<td>Disability weight</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<tr>
<td>GATT</td>
<td>General agreement on Trade and Tariff</td>
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<tr>
<td>GU</td>
<td>Genitourinary</td>
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<tr>
<td>H2O2</td>
<td>Hydrogen peroxide</td>
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<tr>
<td>HR P</td>
<td>Horse-radish peroxidase</td>
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<tr>
<td>IELISA</td>
<td>Indirect Enzyme Linked Immuno-sorbent Assay</td>
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<tr>
<td>ICFTU</td>
<td>International Complement Fixation Unit</td>
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<tr>
<td>IM</td>
<td>Intra muscular</td>
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<tr>
<td>IMI</td>
<td>Intramammary infusion</td>
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<tr>
<td>IV</td>
<td>Intravenous</td>
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<tr>
<td>KCDFs</td>
<td>Kuku cooperative dairy farms</td>
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<tr>
<td>LA-OTC</td>
<td>long-acting oxytetracycline</td>
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<tr>
<td>LDCs</td>
<td>Less developing countries</td>
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<tr>
<td>LDPS</td>
<td>livestock development planning system</td>
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<tr>
<td>M.D</td>
<td>Medical Doctor</td>
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<tr>
<td>MAb</td>
<td>Monoclonal Antibody</td>
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<td>MMWR</td>
<td>Mortality and Morbidity Weekly Report</td>
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<td>MRT</td>
<td>Milk Ring Test</td>
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<tr>
<td>OD</td>
<td>Optical density</td>
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<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>OIE</td>
<td>Office International des Epizooties</td>
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<tr>
<td>PBS</td>
<td>Phosphate buffer saline</td>
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<tr>
<td>PCR</td>
<td>polymerase chain reaction</td>
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<tr>
<td>PI</td>
<td>percentage inhibition</td>
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<tr>
<td>PO</td>
<td>Per Oss</td>
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<tr>
<td>PP</td>
<td>per cent positivity</td>
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<td>RBSA</td>
<td>Rose-Bengal slide agglutination</td>
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<td>RBT</td>
<td>Rose –Bengal Test</td>
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<td>SAT</td>
<td>Serum agglutination test</td>
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<td>S-LPS</td>
<td>Smooth Lipopoly Saccaride</td>
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<tr>
<td>ST</td>
<td>streptomycin</td>
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<td>STA</td>
<td>Standard tube agglutination</td>
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<td>TAT</td>
<td>Tube Agglutination Test</td>
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<td>TMP-SMZ</td>
<td>trimethoprim/sulfamethoxazole</td>
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<tr>
<td>WHO</td>
<td>World Health Organization</td>
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<td>WTO</td>
<td>World Trade Organization</td>
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## LIST OF MAPS

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Appendix 5  Sources of data.
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Appendix 8  Differential equations for the fitting and simulation of vaccination.