REPUBLIC OF KENYA

THIRTEENTH PARLIAMENT- THIRD SESSION

SENATE STANDING COMMITTEE ON AGRICULTURE, LIVESTOCK AND FISHERIES

REPORT ON A PETITION ON THE CATASTROPHIC MAIZE DISEASES THAT FARMERS IN BOMET COUNTY HAVE ENDURED FOR THE LAST TWELVE YEARS

Clerk's Chambers,
Parliament Buildings,
NAIROBI.

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LIST OF ABBREVIATIONS

MoALD - Ministry of Agriculture and Livestock Development

KALRO - Kenya Agricultural and Livestock Research Organization

PCPB - Pest Control Products Board

MLND - Maize Lethal Necrosis Disease

CABI - Center for Agriculture and Biosciences International

CIMMYT - International Maize and Wheat Improvement Center

MITT - Multi-Institutional Technical Team

ICIPE - International Centre of Insect Physiology

UoN - University of Nairobi

JKUCAT - Jomo Kenyatta University of Agriculture and Technology

IPM - Integrated Pest Management

Report on a petition on the Catastrophic Maize Diseases that farmers in Bomet County have endured for the last twelve years

PRELIMINARIES

ESTABLISHMENT AND MANDATE OF THE COMMITTEE

The Senate Standing Committee on Agriculture, Livestock and Fisheries is established under standing order 228 (3) of the Senate Standing Orders. Pursuant to the provisions of the Fourth Schedule of the Standing Orders, the Standing Committee on Agriculture, Livestock and Fisheries is assigned to consider all matters relating to agriculture, irrigation, livestock, fisheries development and veterinary services.

Mandate of the Committee

The Standing Order 228(4) (a) assigns the Standing Committee to investigate, inquire into, and report on all matters relating to the mandate, management, activities, administration and operations of the assigned Ministries and departments. In executing its mandate, the Standing Committee oversees the following State Departments:

1. Ministry of Agriculture and Livestock Development;

    (i) The State Department for Crops Development and;

    (ii) The State Department for Livestock Development

2. Ministry of Sanitation, Water and Irrigation.

    (i) State Department for Irrigation.

3. Ministry of Mining, Blue Economy and Fisheries.

    (i) State Department for Blue Economy and Fisheries.

The Committee also oversees the following State Agencies among others: -

1. Agriculture and Food Authority (AFA);

2. Agricultural Finance Corporation (AFC);

3. Agricultural Development Corporation (ADC);

4. Kenya Seed Company (KSC);

5. Kenya Plant Health Inspectorate Services (KEPHIS);

6. Kenya Agricultural and Livestock Research Organization (KALRO);

7. Kenya Veterinary Vaccine Production Board (KVVPB);

8. Kenya Veterinary Board (KVB);

9. Kenya Meat Commission (KMC);

10. Kenya Dairy Board (KDB);

11. Kenya Leather Development Council (KLDC);

12. Kenya Fisheries Service (KFS);

13. Kenya Fish Marketing Authority (KFMA);

14. Kenya Marine and Fisheries Research Institute (KEMFRI);

15. Kenya Fishing Industries Corporation;

16. National Cereals and Produce Board (NCPB); and

17. National Irrigation Board (NIB).

The Committee also works closely with the Council of Governors (CoG), the County Assemblies Forum (CAF) and non-state actors including among others-

1. Kenya Private Sector Alliance (KEPSA);

2. Agricultural Council of Kenya (AgCK)

3. Food and Agriculture Organization (FAO);

4. Kenya National Farmers' Federation (KENAFF);

5. Centre for Agriculture and Bioscience International (CABI); and

6. Agricultural Industry Forum (AIF).

MEMBERSHIP OF THE COMMITTEE

The Committee is comprised of the following Members-

1. **Sen. James Kamau Murango, MP**	-	**Chairperson**
2. **Sen. Alexander Munyi Mundigi, MP**	-	**Vice-Chairperson**
3. Sen. Moses Otieno Kajwang', MP	-	Member
4. Sen. Enoch Kiio Wambua, CBS, MP	-	Member

5. Sen. Daniel Kitonga Maanzo, MP   -   Member

6. Sen. Beth Kalunda Syengo, MP   -   Member

7. Sen. Wahome Wamatinga, MP   -   Member

8. Sen. Allan Kiprotich Chesang, MP   -   Member

9. Sen. David Wafula Wakoli, MP   -   Member

CHAIRPERSON'S FOREWORD

Mr. Speaker Sir,

At its sitting of the Senate held on Thursday, 29th June 2023 the Honorable Speaker reported to the Senate that he was ceased of a petition through the Clerk, by Mr. Kerich Kipronoh Hillary, a resident of Bomet, in respect to Catastrophic Maize Disease (Maize Lethal Necrosis Disease (MLND)) that farmers in Bomet County have endured since 2011 when it was first reported. Pursuant to Standing Order 238(1) of the Senate Standing Orders the petition stood committed to the Standing Committee on Agriculture, Livestock and Fisheries.

Mr. Speaker Sir,

The petition highlights the severe implications of Maize Lethal Necrosis Disease (MLND) on food security and the agricultural landscape in Kenya. Since its identification in September 2011, MLND has drastically affected households, making it increasingly difficult for families to afford basic meals. This situation has been exacerbated by rising costs associated with education and healthcare, further straining the resources of affected communities.

A significant concern raised in the petition is the withdrawal of support from development stakeholders, such as Apollo Agriculture, who have stopped providing input loans to farmers due to fears of potential losses. This lack of financial assistance has left farmers vulnerable and struggling to sustain their livelihoods. The disease, which was first detected in Kipisarwet, has since spread throughout Bomet County, leading to an alarming 90% crop loss in 2012. As a result, maize farming has become an unattractive investment, discouraging farmers from engaging in this critical agricultural activity.

The petition, further, underscores the absence of effective intervention measures from both the National and County governments. Farmers have not received adequate guidance on managing the disease, exploring alternative crop varieties, or ensuring the quality of maize seeds. This lack of support not only hampers farmers' ability to cope with MLND but also raises concerns about the potential for the disease to spread to other maize-growing regions in Kenya, thereby threatening national food security.

Mr. Speaker Sir,

Despite efforts to engage with relevant authorities regarding these pressing issues, the petitioners felt that their concerns had not been satisfactorily addressed. Importantly, the petition clarifies that none of the matters raised are currently pending in any court or legal body, indicating a need for urgent action and intervention to mitigate the impact of MLND on farmers and food security in the region.

Mr. Speaker Sir,

In a bid to address the issues canvassed in the petition, the Committee resolved to conduct an inquiry on the issues raised in the Petition. In this regard the Committee invited the petitioner to elaborate on the issues raised and to share supporting evidence. The Committee held a meeting with the petitioner, Mr. Kerich Kipronoh Hillary on September, 19th 2023.

The Committee thereafter met with the Ministry of Agriculture and Livestock Development and the Kenya Agriculture and Livestock Research Organization (KALRO) on May, 23rd 2024 in a bid to investigate into the issues raised in the petition. The Committee held a total of two (2) meetings.

The Committee submits the report as its response to the Petitioner pursuant to section 5(3) of the Petition to Parliament Act and Standing Order 238 (2) of the Senate Standing Orders.

The Committee thanks the Offices of the Speaker of the Senate and the Clerk of the Senate for the support extended to the Committee in the execution of its mandate. The Committee further extends its appreciation to the parties to the matter; namely, the Ministry of Agriculture and Livestock Development (MoALD), KALRO, Sen. Wakili Hillary Sigei, M.P. (Bomet County) and the petitioner Mr. Kerich Kipronoh Hillary for their submissions and contribution to the resolution of this matter.

Mr. Speaker Sir,

I want to assure the petitioner that anything affecting the farmers in this Country is affecting food security and the Committee will investigate all the issues affecting food value chains.

Mr. Speaker Sir,

It is now my pleasant duty and privilege, on behalf of the Committee, to present this Report of the Standing Committee on Committee on Agriculture, Fisheries and Livestock on the Petition by Mr. Kerich Kipronoh Hillary, a resident of Bomet County, on Catastrophic Maize Disease that farmers in Bomet County have endured since 2011.

Signed.................................. Date ...21/11/24...........................

Report on a petition regarding the Catastrophic Maize Diseases that farmers in Bomet County have endured for the last twelve years

ADOPTION OF THE REPORT OF THE STANDING COMMITTEE ON AGRICULTURE, LIVESTOCK AND FISHERIES ON A PETITION REGARDING THE CATASTROPHIC MAIZE DISEASES THAT FARMERS IN BOMET COUNTY HAVE ENDURED FOR THE LAST TWELVE YEARS

We, the undersigned Members of the Senate Standing Committee on Agriculture, Livestock, and Fisheries, do hereby append our signatures to adopt this Report –

	Name	Designation	Signature
1.	Sen. James Kamau Murango, MP	Chairperson	
2.	Sen. Alexander Munyi Mundigi, MP	Vice-Chairperson	
3.	Sen. Moses Otieno Kajwang', MP	Member	
4.	Sen. Enoch Kiio Wambua, CBS, MP	Member	
5.	Sen. Daniel Kitonga Maanzo, MP	Member	
6.	Sen. Beth Kalunda Syengo, MP	Member	
7.	Sen. Wahome Wamatinga, MP	Member	
8.	Sen. Allan Kiprotich Chesang', MP	Member	
9.	Sen. David Wafula Wakoli, MP	Member	

SEN. JAMES KAMAU MURANGO, M.P.

CHAIRPERSON,

STANDING COMMITTEE ON COMMITTEE ON AGRICULTURE,

LIVESTOCK, FISHERIES AND BLUE ECONOMY

CHAPTER ONE: INTRODUCTION

1.1 The Right to Petition

1. The right of every person to present petitions to public authorities is provided for under Article 37 of the Constitution. Further, Article 119(1) provides that 'Every person has a right to petition Parliament to consider any matter within its authority, including to enact, amend or repeal any legislation.'

2. Parliament enacted the Petition to Parliament (Procedure) Act (No. 12 of 2012) to make provision for the procedure for the exercise of this right. Further, Part XXVII of the Senate Standing Orders also makes provision of how this right may be exercised.

1.2 Background of the Petition

3. On June 12, 2023, Mr. Kerich Kipronoh Hillary, a resident of Bomet County, submitted a petition to the Senate under Standing Order 232(1)(a) addressing the ongoing challenges posed by the Catastrophic Maize Disease, the Maize Lethal Necrosis Disease (MLND), which has afflicted local farmers since it was first reported in 2011.

4. The petition highlights the severe impact of MLND on food security and the livelihoods of residents who depend heavily on maize as a staple crop. Since its emergence, MLND has led to significant crop losses, with a staggering 90% loss reported in 2012, making maize farming increasingly unattractive to investors.

5. At its sitting of the Senate held on Thursday, 29th June, 2023 the Honorable Speaker reported to the Senate that he was ceased of a petition through the Clerk pursuant to Standing Order 232(1)(a). Consequently, the petition stood committed to the Committee on Agriculture, Livestock and Fisheries pursuant to Standing Order 238(1) for consideration and to table a report back to the House pursuant to Standing Order 238(2).

6. On September 19, 2023, the Committee met with the petitioner to listen to his oral submission, during which Mr. Hillary provided further context and details regarding the disease's impact on local agriculture. Despite the critical situation, the petition outlines a concerning lack of support from development stakeholders, who have withdrawn input loans due to fears of losses, leaving farmers in a precarious position without guidance on disease management or alternative crop varieties.

7. Therefore, the petitioner's prayers were that the Senate looks into the matter with a view of ensuring the following:

   (1) Determining measures, the Kenyan Government will implement to provide intervention for rural farmers affected by MLND in Bomet County.

   (2) Implementing stringent supervision of maize farming and investigate the potential spread of MLND to other crops and its effects on human and animal health.

   (3) Recommending a compensation mechanism for farmers affected by compromised seed quality leading to production losses.

   (4) Suggesting measures for development stakeholders to ensure farmers are not alienated in future agricultural crises.

   (5) Implementing effective control measures to combat the spread of MLND.

   (6) Regulating maize seed sales to ensure access to disease-resistant varieties.

   (7) Providing crop insurance to mitigate losses and offer a safety net for farmers.

   (8) Identifying and promoting alternative crops to ensure sustainable food security for farmers and their families.

8. Standing order 239 of the Senate Standing Orders requires the Clerk to, within fifteen days of tabling of the report on a petition under Standing Order 238 (Committal of Petitions); submit a copy of the report to the petitioner or petitioners.

1.3 Key highlights from the petitioner's prayers

9. The Committee highlighted some of the key issues as captured below from the petitioner's prayers:

1. Implications of MLND on Food Security

10. The petition emphasizes MLND's devastating impact on food security within affected communities. As maize is a primary food source, any decline in production directly threatens household food availability and nutritional security.

11. Families face rising costs associated with education and healthcare, exacerbating their struggles to afford basic necessities amidst declining agricultural productivity.

12. The socio-economic ramifications extend beyond individual households; entire communities reliant on maize farming are experiencing increased poverty levels and food insecurity.

2. Withdrawal of Support from Development Stakeholders

13. A significant concern raised in the petition is the withdrawal of support from development stakeholders like Apollo Agriculture.

14. This withdrawal arises from fears of potential losses due to MLND, leaving farmers without essential input loans and financial assistance.

15. The disinvestment in maize farming has made it an unattractive venture for many farmers, discouraging engagement in this vital agricultural sector.

16. This cycle of disinvestment not only impacts individual farmers but also threatens the broader agricultural economy in Kenya.

3. Government Response and Intervention Measures

17. The petition highlights a critical lack of effective intervention measures from both National and County governments.

18. Farmers reported inadequate guidance on managing MLND and exploring alternative crop varieties. This lack of support raises alarms about the potential for MLND to spread beyond Bomet County to other maize-growing regions, further jeopardizing national food security.

CHAPTER TWO: CONSIDERATION OF THE PETITION

2.1 Conduct of inquiry into the Petition

19. Pursuant to the Senate Standing Orders and the Petition to Parliament (Procedure) Act, the Committee proceeded to consider the petition and to seek stakeholder submissions. Those who submitted their submissions to the Committee included Mr. Kerich Kipronoh Hillary (herein the petitioner), Sen. Wakili Hillary Sigei, M.P. (Senator Bomet), Ministry of Agriculture and Livestock Development and the Kenya Agricultural and Livestock Research Organization (KALRO).

20. The Committee held a session with the petitioner Mr. Kerich Kipronoh Hillary on 19th September 2023 to deliberate on the issues raised and to afford him an opportunity to share supporting evidence relevant to the petition.

21. Further the Committee met with Sen. Wakili Hillary Sigei, M.P, the area Senator on 26th September 2023. The Senator submitted that the issues raised in the petition were of great concern to the people of Bomet County. The Committee also met the Ministry of Agriculture and Livestock Development and the Kenya Agricultural and Livestock Research Organization (KALRO) on 23rd May 2024.

22. The Ministry of Agriculture and Livestock Development submitted that they were aware of the challenges faced by tea farmers in Bomet County and were working on strategies to address the issues raised in the petition.

23. On the other hand, Kenya Agricultural and Livestock Research Organization (KALRO) submitted that they had ongoing research to offer preventive and mitigation to the dangerous disease.

CHAPTER THREE: ANALYSIS OF THE SUBMISSIONS

3.1 The Petitioner

24. The petitioner who appeared before the Committee on 19th September 2023, is a resident of Nyangores Ward, Chepalungu Constituency. He highlighted critical issues facing Bomet County, particularly regarding maize production and food security.

25. A summary of his submissions is highlighted below:

3.1.1 Overview of Bomet County's Agriculture Sector

26. Bomet County is recognized as one of Kenya's prime maize production areas, contributing significantly to the local economy and food security. With a population of 875,689 (2019 census) and a land area of 1,997.9 km², the county relies heavily on maize, beans, and cowpeas. Maize is vital for the nutritional and economic well-being of approximately 95% of the residents, making its production a priority for local stakeholders.

3.1.2 Impact of Maize Lethal Necrosis Disease (MLND)

27. **Disease Outbreak**: Since September 2011, Bomet County has been grappling with Maize Lethal Necrosis (MLN), a disease that has severely affected food security. The disease first emerged in Kipisarwet and rapidly spread, leading to a devastating loss of 90% of maize crops in 2012. This has made maize farming a risky investment, further complicating the livelihoods of local farmers.

28. **Household Struggles**: The ongoing challenges posed by MLN have forced households to struggle to maintain food security, compounded by other financial burdens such as school fees and medical expenses. This has created a precarious situation for many families relying on maize for sustenance.

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3.1.3 Lack of Support and Intervention

29. **Absence of Assistance:** The petition highlighted the lack of intervention from both the National and County governments. Farmers had not received adequate information on managing MLN, including its health impacts and alternative crop varieties. The absence of stringent control measures for maize seed quality has exacerbated the situation, allowing the disease to persist and spread.

30. **Withdrawal of Financial Support:** Development stakeholders, such as Apollo Agriculture, have ceased providing input loans to farmers in the region due to concerns over potential losses linked to the disease. This withdrawal has left farmers in a difficult position, unable to invest in their crops and exacerbating their financial challenges.

3.1.4 Risk of Wider Spread of MLN Disease

31. The petitioner warned of the potential for MLN to spread beyond Bomet County to other maize-growing regions in Kenya, which could lead to a nationwide maize crop failure. This scenario poses a significant threat to food security across the country, necessitating urgent action to control the disease.

32. The petitioner urged the Senate to take decisive action, including:

    (1) Government Intervention: Implementing measures to support farmers affected by MLN, including stringent supervision of maize farming and investigation into the disease's spread.

    (2) Compensation Mechanisms: Establishing compensation for farmers who suffer losses due to compromised seed quality.

    (3) Support from Development Stakeholders: Encouraging organizations like Apollo Agriculture to continue supporting farmers, even in the face of emerging agricultural diseases.

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(4) Control Measures: Implementing effective strategies to combat MLN, including regulation of maize seed sales to ensure access to disease-resistant varieties and provision of crop insurance to mitigate losses.

(5) Alternative Crops: Promoting the cultivation of alternative crops to ensure sustainable food security for farmers and their families.

3.2 Sen. Wakili Hillary Sigei, MP

33. Sen.Wakili Hillary Sigei, M.P, Senator representing Bomet County, emphasized the severe impact of MLND on maize production, which is a staple crop and primary source of income for many farmers in Bomet. He stressed the urgent need for a multi-faceted approach to combat MLND, including research into resistant maize varieties, improved agricultural practices, and public awareness campaigns.

34. The Senator outlined several measures being implemented in Bomet County to manage the disease. These include promoting crop rotation with non-cereal crops, encouraging early planting, and the use of certified seeds and appropriate fertilizers. He also mentioned the success these mitigations have yielded leading to a reversal on the once serious threat.

35. Senator Sigei called for increased support from the national government and research institutions to develop and distribute MLND-resistant maize varieties suitable for Bomet's agro-ecological conditions. He also requested additional funding for agricultural extension services to educate farmers on best practices for disease management and crop diversification strategies.

3.3 Ministry of Agriculture and Livestock Development

36. The Principal Secretary, State Department for Agriculture appeared before the Committee on 23rd May 2024. In his submissions, he stated that food security in Bomet County and the Country at large has been affected negatively by the Maize

Lethal Necrosis (MLN) disease that was first identified in Kipisarwet area in 2011. The disease has the potential to cause 100% maize crop failure. The Ministry and the County Government of Bomet have employed several strategies and interventions to manage the spread of the disease in the Country.

37. The Ministry of Agriculture and Livestock Development (*herein after the Ministry*) has collaborated with county governments to tackle MLN through a multi-faceted approach through the formation of a Multi-Institutional Technical Team (MITT). The MITT consists of stakeholders from research institutions (KALRO, ICIPE, CYMMIT), regulatory agencies (KEPHIS, PCPB), academia (UoN, Egerton, JKUCAT), the private sector (Agrochemical industry, seed sector), and plant protection officers in State Department for Agriculture. The MITT was formed to investigate and recommend control measures for the disease.

38. In an effort to combat the spread of MLN disease, a targeted awareness campaign was undertaken to educate farmers on best practices for disease management. The information empowered farmers to adopt proactive measures in their fields, mitigating the risk of disease transmission and promoting overall crop health by observing closed seasons, removing infested materials, and enhancing plant vigor through proper fertilization and weed control.

39. The following approaches were adopted to create awareness –

   i. Plant Health Rallies: Before planting season in 2024, extensive awareness campaigns in form of Plant Health rallies were conducted by Trained Technical staff and MITT;

   ii. Barazas: In each of the seventy-five (75) locations in Bomet County, at least one Baraza was conducted. Printed technical materials (briefs, brochures, flyers and posters) were distributed and used as teaching aids. The Kenya Agricultural and Livestock Research Organization (KALRO) enhanced the campaign by providing access to validated KIAMIS data empowering county teams with farmers' contacts for ease of scheduling barazas; and

iii. Mass media: Radio programs with tailored messages for MLN and its management were used to reach a wider audience of farmers. The messages were delivered on local media channels that broadcast in vernacular languages.

40. Farmers have been sensitized to embrace crops diversification as an initiative of reducing the viral load in their fields. The aim of this initiative is to diversify agricultural practices and provide farmers with viable crop options that can contribute to a more resilient and sustainable farming systems. Some of the alternative crops are beans, chickpea, pigeon-peas, cowpeas, sunflower, canola, spring onions, potatoes, pyrethrum, kales, cabbages, indigenous vegetables, sweet potatoes.

41. The Ministry held a training in Naivasha for Extension Officers from Bomet County on management of Maize Lethal Necrosis Disease (MLND).

42. The use of fake and uncertified maize seeds by farmers in Bomet County exacerbated the spread of Maize Lethal Necrosis Disease (MLND). Kenya Seed Company opened a seed shop in Bomet County to ensure farmers have access to certified and tolerant maize seed.

3.3.1 Compensation and Support Measures

Maize Lethal Necrosis Disease (MLND) is a transboundary disease that affects all maize crops irrespective of intended end use either as seed, grains or animal feed.

43. Kenya was the first Country in East Africa to confirm the occurrence in 2011. However, within one year, the disease spread to all East African Countries, South African region and even West African region. The disease spread to all maize growing regions in the country, and all available maize varieties were found susceptible.

44. Despite the severe impact of MLN, the Ministry rejected a 2012 petition for farmer compensation due to the absence of a government policy on compensating losses from transboundary and invasive pests.

45. Instead, the Ministry, through the Traditional High Value Crops Programme provided

alternative planting materials like beans, Irish potatoes, sweet potatoes, cassava, sorghum, and millet to support affected farmers.

46. The Ministry also recommended that other development stakeholders use transparent criteria to ensure fair distribution of benefits to farmers. Due to various measures put in place by the Government, the severity and spread of the disease declined over time in most regions of the Country. There have been sporadic outbreaks of MLN during some seasons but the disease pressure has generally declined.

3.3.2 Measures followed by development stakeholders

47. Development partners and stakeholders set their criteria to determine the farmers who qualify to receive benefits when they incur losses from emergencies of crop or livestock diseases, the Government on its part put in place policies to be adhered to by development partners and stakeholders such as Apollo Agriculture who provide farmers with inputs and other services in the event of the emergence of crop or animal diseases.

3.3.3 Control Measures and Alternative Crops

48. The County Extension Service providers are encouraged to adopt the Farmer Field School Approach which offers a very effective season-long practical learning experience to the farmers on effective MLN disease control measures. Some of the recommended interventions include –

i. **Enforcement of closed seasons for maize**: Bomet County is implementing a three-month maize-free period. This approach helps in avoiding continuous maize cultivation or relay planting, with the aim of disrupting the transmission cycle of MLND. This approach involves enforcement and training of farmers on the importance of implementation compliance and providing planting guidelines, providing high-quality alternative planting materials, establishing plant health clinics, demonstrating tolerant maize varieties, and building the capacity of

technical teams. Registered pesticides are available for controlling vectors like maize thrips and aphids. Additionally, various disease-resistant maize varieties have been released commercially.

ii. **Access to high-quality alternative planting materials**: Counties to improve access to alternative high value crop planting materials by bulk order e.g., certified irish potato seeds, high-value *Nyota* beans, leafy vegetables for distribution to farmers for planting in the 2nd season.

iii. **Plant Health Clinics**: Counties to mainstream 'Plant Health Clinics' model to offer farming community avenues for seeking pest and disease diagnostic support on a regular basis during market days. Plant Health Clinics were spearheaded by the Ministry with support of CABI in over twenty (20) Counties.

iv. **Demonstrations on tolerant maize varieties**: Demonstrations on planting of MLND-resistant, maize varieties. The tolerant maize variety require integration with other IPM (Integrated Pest Management) measures for better effectiveness. Setting up demonstration plots will enhance the adoption of these resistant varieties.

v. **Capacity Building and Technical team**: MITT to review and update MLND technical information materials and further capacity build County technical teams starting with Counties with high disease prevalence.

vi. **Pesticide use to control Maize Lethal Necrosis Disease (MLND)**: Control of key MLND insect vectors such as aphids and thrips is necessary in order to prevent transmission of MLND viruses. Approved and registered pest control products for control of the insect vectors is being promoted among the farmers and demonstration materials are purchased and distributed to farmers.

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3.3.4 Regulation of Maize seed for disease resistant varieties to farmers

49. The Ministry of Agriculture and Livestock Development is responsible for regulating marketing and distribution of maize seed. The Ministry has endeavored to ensure farmers have access to disease resistant varieties.

50. There are nineteen (19) seed varieties which have been tested and released for commercialization to mitigate against MLND. The disease resistant maize varieties available in the market are:

    a) SC 447, SC 445, and SC Duma 441 varieties from Kenya Seed Company;

    b) DK777 variety from Monsanto Kenya Limited;

    c) WE5135, 5139, 5140 varieties from CIMMYT/AATF/KALRO – Katumani;

    d) WE6109, WE7118, WE7119 varieties from AAFT;

    e) MH502 (Taji) variety from East African Seed Company Limited; and

    f) KALZm-H4-301, KALZm-H4-302, and KALZm-H4-303 varieties from KALRO-Kabete.

3.3.5 Crop Insurance

51. The Ministry of Agriculture and Livestock Development is implementing a comprehensive Crop Insurance Program to cushion farmers from losses associated with crop failure due to climatic conditions, floods, pest and disease.

3.4 Kenya Agricultural and Livestock Research Organization (KALRO)

3.4.1 First Occurrence and Symptoms of Maize Lethal Necrosis Disease (MLND)

52. The Kenya Agricultural and Livestock Research Organization (KALRO) appeared before the Committee on 23rd May 2024.

53. KALRO submitted that MLND was first reported in Bomet County in September

2011, affecting approximately two-hundred (200) hectares of maize. The disease spread rapidly, reaching various maize-growing regions in Kenya by 2012.

54. The symptoms of the disease include bright yellowing of leaves, drying up, lack of pollen in tassels, premature drying of husks, and incomplete grain filling. These symptoms can appear as early as two weeks after germination.

3.4.2 Early and Subsequent Actions

55. A Multi-Institutional Technical Team (MITT) was formed to investigate the cause and spread of MLN, identifying maize chlorotic mottle virus (MCMV) and sugarcane mosaic virus (SCMV) as the causative agents. Efforts included developing informational materials, training agricultural staff, and conducting awareness campaigns. Additionally, KALRO and CIMMYT established an MLN screening site, resulting in the release of over 16 MLN-tolerant maize varieties.

3.4.3 Recommendations for Sustainable Management

56. KALRO emphasizes the importance of continuous management to combat MLN. Key recommendations include using certified disease-resistant seeds, timely planting, practicing crop rotation, and maintaining field sanitation. Controlling insect vectors such as thrips and aphids is crucial, and regular scouting for pests is advised. These measures should be integrated and consistently applied to suppress MLN effectively.

3.4.4 Proposed Action Plan

57. Under the guidance of the Principal Secretary for Agriculture, an action plan was developed in December 2023 for Bomet County. The plan focuses on deploying MLN-tolerant seeds, implementing a closed season for maize, monitoring and controlling disease vectors, and raising awareness through various channels. The plan also encourages crop diversification and community involvement.

58. In conclusion KALRO acknowledged the significant progress that had been made in addressing MLND through strategic initiatives and collaborations. However, ongoing management and proactive measures are essential for complete eradication. Continuous vigilance and adaptation to new challenges will ensure the long-term health and productivity of maize crops, securing food security and economic stability for Bomet County and other affected regions.

3.5 Kenya Plant Health Inspectorate Service (KEPHIS)

3.5.1 Background Information

59. Maize Lethal Necrosis disease (MLND) is a result of a combination of two viruses Maize chlorotic mottle virus (MCMV) and any of the potyvirus e.g., the Sugar Cane Mosaic Virus, Wheat Streak Mosaic Virus or Maize Dwarf Mosaic Virus. The double infection of the two viruses gives rise to what is known as Maize Lethal Necrosis disease (MLND). In Kenya it has been reported that the double infection is caused by Maize Chlorotic Mottle Virus (MCMV) and the Sugar Cane Mosaic Virus.

60. MLND is mainly spread by vector, transmitting the disease from plant to plant and field to field. The most common vectors are maize **thrips and aphids.** Thrips vectors maize chlorotic mottle virus and sugarcane mosaic virus is vectored by aphids. The disease can also be transmitted mechanically and through seed.

61. The disease is more prevalent in areas where farmers practice relay cropping, where vectors carry the viruses from on crop to the next. This is a common practice in South Rift, where Bomet is located and farmers are always encouraged to have a break/closed season (avoid relay cropping of maize). The impact of the disease is not much in North Rift as there is usually a break from one season to the next.

3.5.2 History of introduction of the disease

62. In Kenya the first occurrence of unfamiliar maize disease was first reported in September 2011 in parts of Bomet County (Longisa Division) affecting about 200 Ha of the second season maize crop. The effects of the disease were sudden; devastating and the cause was yet unknown. Local farmers called it 'Koroito', which is the vernacular name for plague. By the end of 2011 the disease had spread to the higher

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altitudes of Bomet (2100) m a.s.l), the neighbouring Chepalungu, Narok South, Narok North and Naivasha sub- counties. By 2012 the disease had been reported in all maize growing regions in the country except North Eastern.

63. The initial symptoms of the disease were varied, but apparently restricted to the leaf, stem and ears. Typically, early leaf symptoms were mottling and chlorosis that progressed to give some deformity and then extensive necrosis. Stems were also seen to show deformity, foliar infection was often associated with the leading growth, with early formed leaves remaining green. For plants with foliar or stem infection, grain filling was shown to be markedly reduced. In affected fields, infection rates approaching 100% were typical and yields were severely affected.

3.5.3 Identification done by FERA

64. Initial attempts at diagnosis using traditional approaches failed to identify any potential pathogens in the diseased plant material (fungal, bacterial or viral) and as a result the Next-Generation Sequencing (NGS) approach using 454-sequencing was deployed.

65. This work was performed at the Food and Environment Research Agency (FERA) labs in the UK, in collaboration with CAB International (CABI). The sequencing highlighted the presence of *Maize chlorotic mottle virus* (MCMV) and a variant isolate of *Sugarcane mosaic virus* (SCMV), a combination of viruses known to cause Maize Lethal Necrosis Disease (MLND).

66. Over 90% of both viral genome sequences were obtained, allowing strain characterization and the development of specific real-time PCR assays which were used to confirm the presence of the virus in material with symptoms from six different fields in two different regions of Kenya. The developed real-time PCR assays were later validated and adopted for use at KEPHIS for routine diagnosis of maize seed samples. The yield loss due to MLN is estimated to be 50-100 % in Kenya (Mahuku et al., 2015; De Groote et al., 2016 and Mwatuni et al 2020).

3.5.4 Interventions

i. **Awareness creation**: from the initial period Surveillances carried out Seed certification and mandatory seed testing for all maize seed lots grown in Kenya and imported;
ii. Meeting giving a decision for testing of all seed lots for MLND (minutes) and mandatory seed treatment with systemic insecticides;
iii. Release of resistant varieties;
iv. Maize agronomic practices - farmers advised to observe a break season to avoid carry over of disease from one season to the next;
v. Stringent control measures on seed maize offered for sale; and
vi. Certification for MLND, post control, inspection tolerances at field level for seed crops.

3.5.5 Confirm distribution of the disease

67. KEPHIS is aware of the status of the Maize Lethal Necrosis Disease (MLND) in the country including Bomet County (Maize survey report 2023, Maize survery report 2022, Maize survey report 2018).
68. Interventions to prevent spread to other maize producing counties: -

i. Communication - KEPHIS had communication to the seed growers on MLND Communication to famers in the different production areas;
ii. Training for seed producers; and
iii. Awareness creation to famers.

3.5.6 Response to Petitioner's Prayers

a) Recommend compensation mechanism that should be followed by either the Government of Kenya or any maize seed manufacturer and or reseller found culpable to have compromised on planting seeds quality leading to production losses. Section 10 of the Seeds and Plant Varieties Act Cap 326 provides for offences, penalties and fines related to seed quality. Since MLND is established in the country, prevalent in the maize growing areas and the vectors are naturally

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present, the risk and opportunity for infection of maize crops is unavoidable. Use of a closed **season** has been identified as a key intervention;

b) Implementation of effective control measures to combat the spread of MLND:

- KEPHIS is already implementing the seed certification field inspections and rejection of crops showing disease symptoms, management of vectors (thrips, aphids), testing of all seed lots produced locally and those imported for the viruses. Any seed testing positive for any of the viruses is not authorized for sale and Surveillance and monitoring.

- KEPHIS encourages farmers to practice a **closed season.**

c) Regulations of maize seed sale to ensure farmers have access to disease-resistant varieties. KEPHIS has tested and facilitated release of 16 MLN tolerant maize varieties developed by various breeders, some are already in the market and others are at different stages of seed multiplication.

d) Identification and promotion of alternative crops that can be planted in place of maize to ensure farmers and their families have sustainable food security KEPHIS has been promoting avocado production as an alternative the suitable areas including Bomet Country for export market.

3.5 Pest Control Products Board (PCPB)

69. Maize lethal necrosis disease (MLND) was first reported in Kenya in Bomet County in September 2011. Within a span of one year, the disease had been reported and confirmed in Eastern, Rift Valley, Nyanza, Western, Nairobi and Central regions. The MLN disease is caused by a combination of two viruses; the Sugarcane mosaic *virus* (SCMV) and Maize *chlorotic mottle virus* (MCMV). The transmission of MCMV can be mechanical, by several insect vectors (maize thrips, maize rootworms, leaf beetles and leaf hoppers) and by seeds. The SCMV is transmitted by aphids. Continuous maize production in a field was observed to greatly increase the incidence of the viruses and vectors. Infected maize plants show severe symptoms that result in the cobs not having grains or rotten grains, thus drastically affecting yields.

70. Soon after MLND was reported, the government set up a multi-disciplinary technical team to assess the situation and come up with ways of managing the problem. A survey on MLND by the Multi-disciplinary technical team in mid-July 2012 observed the presence of the disease in most maize growing areas in Kenya. The multi-disciplinary technical

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team was composed of Ministry of Agriculture, Livestock and Fisheries (MOALF-PPSD), Kenya Agricultural Research Institute, (now KALRO), Kenya Plant Health Inspectorate Service (KEPHIS), Pest Control Products Board (PCPB), University of Nairobi (UON) and the International Centre for Insect Pest Ecology (ICIPE).

71. Being a viral disease, there are no pest control products known to control the virus directly. However, from literature, the viruses can be transmitted by several insect vectors, through mechanical transmission and by seeds. The potential common vectors identified in Kenya are: - maize thrips, maize rootworms, leaf beetle aphids and leaf hoppers.

72. The Pest Control Product Board, being a Statutory body in charge of regulation of Pest Control Products in Kenya carried out efficacy trials at Longisa, Bomet County and Sunripe farm in Naivasha in October 2012 to 2013 on a number of pest control products in collaboration with the Agrochemical industry and Kenya seed Company to manage the vectors. Twenty-one (21) products were tested in various application regimes including seed dressing and foliar application on maize.

73. Seed dressing with some pesticides followed with foliar application delayed disease manifestation and reduced disease incidence and severity. Following various trials, one product, PONCHO FS 600 Flowable concentrate containing Clothianidin 600g/L was registered by PCPB as a Seed dresser insecticide for the control of Aphids in Maize followed by foliar spray with Thunder OD 145 for Thrips control for reduction of Maize Lethal Necrosis Disease (MLND). The details of the products are available to the public through the PCPB website, https://www.pcpb.go.ke.

74. The multi-disciplinary technical team recommended various options of managing MLN and preventing spread to new locations. They recommended integrated pest management practices encompassing cultural control such as closed season, rogueing infected plants, practicing field hygiene, crop rotation and crop diversification, vector control using seed treatment followed by foliar sprays and host plant resistance.

75. The multi-disciplinary technical team also developed a training manual for Maize Lethal necrosis in 2013 to guide extension staff and other service providers. The Ministry, through the MITT, implemented various interventions to mitigate against this disease. Although the incidence and severity of the MLND was noted to have reduced significantly following the

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proposed management interventions, there has been a recent resurgence of MLND in Bomet County and other areas.

76. A workshop on enhancing management of Maize Lethal Necrosis (MLN) Disease took place from 4th to 8th December 2023 at Dairy Training Institute, Naivasha. The workshop was attended by members of the Multi- Institutional Technical Team (MITT) including PCPB, KEPHIS, KALRO, PP&FSD, University of Nairobi, CABI, CYMMIT, private sector and ICIPE. Agricultural officers from Bomet County were also present.

   i. Technical materials for awareness creation were developed i.e., a technical brief, a poster and a flier;

   ii. Agricultural extension officers from Bomet County were trained; and

   iii. An action plan for management of MLN in Bomet County was developed.

77. A public launch of interventions took place on Tuesday, 16th January 2024 in Bomet County, Bomet town where PCPB participated. Hon. Franklin Linturi, the Cabinet Secretary, Ministry of Agriculture and Livestock Development was the chief guest in the function. The function was attended by the PS, state department for crops, the Bomet County Governor, local MPs, County Commissioner, CEOs of various agencies in the Ministry of agriculture, chairpersons of the agencies and farmers.

78. Three activities took place during the function:

   i. Launching of MLND management initiative in the county. Kenya Seed Company unveiled a new maize variety that is tolerant to MNLD which will help the farmers fight the disease. All the MITT members showcased different technologies and approaches in MNLD management. PCPB has registered one product (PONCHO FS 600) for seed dressing against thrips and aphids and one for foliar application (Thunder OD 145);

   ii. Opening of Kenya Seed branch in Bomet County and flagging off seed distribution in the county. The opening of the Kenya Seed Company, Bomet branch will reduce sale of fake maize seeds in the county; and

   iii. Flagging off of four mobile maize driers to different wards in Bomet County. The driers will help the farmers in management of post-harvest losses and aflatoxin poisoning in maize thus improving food safety.

79. PCPB was represented by the CEO and technical staff in the function. The attendants were taken through the following areas by PCPB:

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i. The pesticides registered for management of MLND;
ii. Reading and interpretation of pesticides label;
iii. How to access PCPB website and how to search for different kinds of information; and
iv. How to recognize illegal pesticides and mitigation measures

CHAPTER FOUR: COMMITTEE OBSERVATIONS AND RECOMMENDATIONS

4.1 Committee Observations

80. Following stakeholder engagements and an analysis of the submission from the various stakeholders the Committee made the following observations: -

1. Impact on Food Security

81. MLND drastically reduced maize production, which is a staple food for many households in Kenya. The disease has been associated with crop losses ranging from 70% to complete failure in severely affected areas. This decline in maize yield directly threatens food security, as maize constitutes a significant portion of the caloric intake for the population.

2. Economic Consequences for Farmers

82. The withdrawal of financial support from development stakeholders like Apollo Agriculture has left farmers without necessary resources for inputs such as seeds and fertilizers. This situation exacerbates their vulnerability and limits their ability to recover from crop losses. The economic implications extend beyond individual farmers to local economies reliant on maize production.

3. Lack of Effective Intervention Measures

83. Both national and county governments have not provided adequate support or intervention measures to manage MLND effectively. Farmers lack guidance on disease management strategies, alternative crop varieties, and quality seed assurance. This absence of structured support hampers immediate recovery efforts and increases the risk of further spread of MLND to other regions.

4. Insufficient Research and Development

84. While there have been efforts to develop resistant maize varieties, the pace of research and dissemination of information remains inadequate. The need for accelerated breeding programs and the introduction of genetically resistant varieties is critical to combatting MLND effectively.

5. Inadequate Awareness and Education

85. There is a significant lack of awareness among farmers regarding MLND and its management practices. Educational initiatives that inform farmers about disease symptoms, management strategies, and available resources are lacking. Enhanced communication channels are necessary to ensure that farmers are well-informed.

6. Potential for Disease Spread

86. The unchecked spread of MLND poses a risk not only to Bomet County but also to other maize-growing regions in Kenya. If not addressed promptly, the disease could lead to widespread agricultural failure across the country.

4.2 Committee Recommendations

87. Based on the findings and observations above, the Standing Committee on Agriculture, Livestock and Fisheries recommends that the following measures be undertaken within six months of approval of this report by the Ministry of Agriculture and Livestock Development and the County Government of Bomet:

1. Strengthening Support Systems for Farmers

88. **Financial Assistance:** Establish programs that provide financial support and input loans specifically targeted at farmers affected by MLND.

89. **Insurance Schemes:** Develop agricultural insurance products that protect farmers against crop losses due to diseases like MLND.

2. Enhancing Government Intervention

90. **Policy Formulation:** The government should formulate policies aimed at supporting research and development in maize production, focusing on disease-resistant varieties.

91. **Coordination Between Agencies:** Foster collaboration between the Ministry of Agriculture, KALRO, and local agricultural bodies to create a unified response strategy against MLND.

3. Research and Development Initiatives

92. **Accelerated Breeding Programs:** Invest in research initiatives that prioritize the development of MLND-resistant maize varieties through genetic engineering and traditional breeding methods.

93. **Field Trials:** Conduct extensive field trials of resistant varieties across different ecological zones to assess their performance under local conditions.

4. Awareness Campaigns

94. **Education Programs:** Implement educational programs aimed at informing farmers about MLND, its symptoms, management practices, and available resources; and

95. **Utilization of Media:** Leverage radio, television, and social media platforms to disseminate information about MLND management strategies effectively.

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5. Integrated Pest Management (IPM) Strategies

96. Promote IPM practices that include cultural controls such as crop rotation, intercropping with resistant varieties, and timely application of pesticides to manage vector populations effectively.

6. Monitoring and Evaluation Framework

97. Establish a framework for monitoring the spread of MLND and evaluating the effectiveness of implemented strategies. Regular assessments will help adapt approaches based on emerging challenges.

LIST OF ANNEXURES

Annex I	Minutes of the Standing Committee on Agriculture, Livestock and Fisheries
Annex II	Petition on the Catastrophic Maize Diseases that farmers in Bomet County have endured for the last twelve (12) years
Annex III	Submission from the Ministry of Agriculture and Livestock Development
Annex IV	Submission from KALRO
Annex V	Submission from KEPHIS
Annex VI	Submission from PCPB
Annex VII	Submission from petitioner

APPENDIX I: MINUTES

MINUTES OF THE HUNDRED AND THIRTY NINTH (139ᵀᴴ) SITTING OF THE STANDING COMMITTEE ON AGRICULTURE, LIVESTOCK AND FISHERIES HELD ON THURSDAY 21ˢᵀ NOVEMBER, 2024 IN COMMITTEE ROOM 7, BUNGE TOWER AT 10:00 A.M.

PRESENT

1.	Sen. James Kamau Murango, MP	-	Chairperson
2.	Sen. Alexander Munyi Mundigi, MP	-	Vice-Chairperson
3.	Sen. Daniel Kitonga Maanzo, MP	-	Member
4.	Sen. David Wafula Wakoli, MP	-	Member
5.	Sen. Beth Kalunda Syengo, MP	-	Member

ABSENT WITH APOLOGIES

1.	Sen. Enoch Kiio Wambua, CBS, MP	-	Member
2.	Sen. Allan Kiprotich Chesang, MP	-	Member
3.	Sen. Wahome Wamatinga, MP	-	Member
4.	Sen. Moses Kajwang, MP	-	Member

SECRETARIAT

1.	Ms. Caroline Njue	-	Clerk Assistant II
2.	Ms. Regina Munyao	-	Legal Counsel I
3.	Mr. Andrew Nyairo	-	Legal Counsel II
4.	Ms. Hillary Cheruiyot	-	Research Officer III
5.	Ms. Rose Ometere	-	Audio Officer
6.	Ms. Juliet Masinde	-	Media Relations Officer
7.	Mr. Benard Sika	-	SAA

MIN/SEN/SCA/921/2024-   **PRELIMINARIES**

The Chairperson called the meeting to order at 10:00 a.m. followed by a word of prayer and introductions.

MIN/SEN/SCA/922/2024-   **ADOPTION OF THE AGENDA**

The agenda was adopted after being proposed by Sen. Alexander Mundigi, MP and seconded by Sen. Beth Syengo, MP as follows –

1. Prayer;
2. Adoption of the Agenda;
3. Confirmation of:
     a) Minutes of the 130th sitting held on Tuesday, 31st October, 2024; and
     b) Minutes of the 131st sitting held on Tuesday, 12th November, 2024,
4. Matters arising;
5. *Adoption of the report on the petition regarding the Catastrophic Maize Diseases that farmers in Bomet County have endured for the last twelve years;*
6. *Consideration of the stakeholder submissions on the Nuts and Oil Crops Bill, 2023 (Senate Bills No. 47 of 2023);*
7. Any Other Business; and
8. Date of the Next Meeting and Adjournment.

MIN/SEN/SCA/923/2024-   **CONFIRMATION OF MINUTES OF THE PREVIOUS SITTING**

The confirmation of Minutes of the 131st sitting held on Tuesday, 12th November, 2024 were confirmed as a true record having been proposed by Sen. Beth Syengo, MP and seconded by Sen. Alexander Mundigi, MP.

MIN/SEN/SCA/924/2024-   **CONSIDERATION OF THE STAKEHOLDER SUBMISSIONS ON THE NUTS AND OIL CROPS BILL, 2023 (SENATE BILLS NO. 47 OF 2023)**

The Committee deferred the consideration of the matrix on the stakeholder submissions on the Nuts and Oil Crops Bill, 2023 (Senate Bills No. 47 of 2023), to be considered at a retreat of the committee in Machakos/Kiambu County in 2025.

MIN/SEN/SCA/925/2024-   **ADOPTION OF THE REPORT ON THE PETITION REGARDING THE CATASTROPHIC MAIZE DISEASES THAT FARMERS IN BOMET COUNTY HAVE ENDURED FOR THE LAST TWELVE YEARS**

The report on the petition regarding the Catastrophic Maize Diseases that farmers in Bomet have endured for the last twelve years was adopted by the Committee having been proposed by Sen. Beth Syengo, MP and seconded by Sen. David Wakoli, MP.

MIN/SEN/SCA/926/2024-   **ANY OTHER BUSINESS**

The Committee resolved to undertake its travel to Arusha Tanzania from travel form 15th to 22nd December, 2024.

MIN/SEN/SCA/927/2024-   **DATE OF NEXT MEETING AND ADJOURNMENT**

The meeting was adjourned at 10:32 a.m. and the next meeting will be by notice.

SIGNED: …………………………….DATE: …………………………….

SEN. JAMES KAMAU MURANGO, MP
(CHAIRPERSON)

MINUTES OF THE HUNDRED AND TENTH (110) SITTING OF THE SENATE STANDING COMMITTEE ON AGRICULTURE, LIVESTOCK AND FISHERIES, HELD ON THURSDAY, 23ᴿᴰ MAY 2024 IN COMMITTEE ROOM 5, FIRST FLOOR, MAIN PARLIAMENT BULDINGS AT 10:00 A.M.

PRESENT

1.	**Sen. James Kamau Murango, MP**	-	**Chairperson**
2.	**Sen. Alexander Munyi Mundigi, MP**	-	**Vice-Chairperson**
3.	Sen. Enoch Kiio Wambua, CBS, MP	-	Member
4.	Sen. Daniel Kitonga Maanzo, MP	-	Member
5.	Sen. Wahome Wamatinga, MP	-	Member
6.	Sen. Beth Kalunda Syengo, MP	-	Member
7.	Sen. David Wafula Wakoli, MP	-	Member
8.	Sen. Wakili Hillary Sigei, MP	-	Bomet County

ABSENT WITH APOLOGIES

1.	Sen. Moses Kajwang, MP	-	Member
2.	Sen. Allan Kiprotich Chesang, MP	-	Member

SECRETARIAT

1.	Ms. Gloria Wawira	-	Clerk Assistant I
2.	Ms. Regina Munyao	-	Legal Counsel
3.	Ms. Belinda Ogolla	-	Research Officer III
4.	Mr. Hillary Cheruiyot	-	Research Officer III
5.	Ms. Rose Ometere	-	Audio Officer
6.	Ms. Violet Nalianya	-	Media Relations Officer
7.	Mr. Joseph Lekisima	-	Fiscal Analyst
8.	Mr. Bernard Sika	-	Sergeant at Arms
9.	Mr. Julius Simiyu	-	Attacheé

IN ATTENDANCE

1. Dr. Paul K Ronoh	-	PS, State Department
for		
		Agriculture
2. Douglas Kogi	-	Director
3. Dr. Eliud Kireger	-	MD, KALRO
4. Dr. Zachary Kinyua	-	Assistant Director, Crop
Health		
5. Prof. Theophilus Mutui	-	MD, KEPHIS
6. Dr. Paul Ngaruiya	-	Ag. GM PCPB
7. Mr. Barasa Wanyonyi	-	PCPB
8. Mr.Collin Marangu	-	PCPB

MIN/SEN/SCA/734/2024- **PRELIMINARIES**

The Chairperson called the meeting to order at 10:20 a.m. followed by a word of prayer.

MIN/SEN/SCA/735/2024- **ADOPTION OF THE AGENDA**

The agenda was adopted after being proposed by Sen. Daniel Kitonga Maanzo, MP and seconded by Sen. Wahome Wamatinga, MP. as follows –

1. *Confirmation of Minutes-*
   a) Minutes of the Hundredth and Ninth (109) sitting held on Tuesday, 21st May 2024 at 10:00 a.m.
2. *Matters arising*
3. *Consideration of Petition on catastrophic maize disease that farmers of Bomet County have endured for the past 12 years, Meeting with stakeholders-*
   a) *Ministry of Agriculture and Livestock Development*
   b) *Pest Control Products Boards*
   c) *Kenya Agricultural Livestock Research Organisation (KALRO)*
   d) *Kenya Plant Health Inspectorate Service (KEPHIS)*
   (Committee Paper No.86)
4. Any Other Business; and
5. Date of the Next Meeting and Adjournment.

MIN/SEN/SCA/736/2024- **CONFIRMATION OF MINUTES**

The confirmation of minutes was deferred to the next sitting.

MIN/SEN/SCA/737/2024- **CONSIDERATION OF PETITION ON CATASTROPHIC MAIZE DISEASE THAT FARMERS OF BOMET COUNTY HAVE ENDURED FOR THE PAST 12 YEARS**

The Committee met with state agencies to deliberate on the Petition on catastrophic maise disease in Bomet County. In the Petition, the Petitioners prayed that the Committee would-

Determine the measures the Kenyan Government will implement to provide intervention measures to the rural poor farmers affected by the maize disease in Bomet County, including but not limited to:

a) Stringent supervision of maize farming and investigation into the potential spread of this disease to other crops and its effects on human and animal health;

b) Recommend compensation mechanism that should be followed by either the government of Kenya or any maize seed manufacturer and or reseller found culpable to have compromised on planting seeds quality leading to production losses;

c) Recommend measures to be followed by other development stakeholders like Apollo Agriculture to ensure that innocent Kenyan citizens are not alienated, and or victimized in the event of emergence of similar crop or animal diseases in the future;

d) Implementation of effective control measures to combat the spread of MLN diseases;

e) Regulation of Maize seed sale to ensure farmers have access to disease-resistant varieties ;

f) Provision of crop insurance to farmers in the region to mitigate crop losses and provide them with a safety net; and

g) Identification and promotion of alternative crops that can be planted in place of maize to ensure farmers and their families have sustainable food security.

Led by the Principal Secretatry they submitted as follows-

Food security in Bomet county and the Country has been affected negatively by Maize Lethal Necrosis (MLN) disease that was first identified at Kipisarwet area in 2011. The disease has the potential to cause 100% maize crop failure. The Ministry and the County Government of Bomet have employed several strategies and interventions to manage the spread of the disease in the Country.

To minimize the negative impact of the MLN disease, the Ministry in collaboration with County Governments have done the following.

1) Stringent supervision of maize farming and investigation into the potential spread of this disease to other crops and its effects on human and animal health

a) Formation of Multi-Institutional Technical Team

The Ministry of Agriculture and Livestock Development in collaboration with Bomet County constituted a Multi-Institutional Technical Team (MITT) to address Maize Lethal Necrosis Disease. The team is comprised of wide range of stakeholders such as National and regional research institutions (KALRO, ICIPE, CYMMIT); Regulatory

agencies (KEPHIS, PCPB); Academia (UoN, Egerton, JKUCAT); Private Sector (Agrochemical industry, Seed Sector) and Plant Protection Officers in State Department for crops Development.

The team was charged with the responsibility of investigating the spread of the disease as well as giving recommendations on how to control and manage the disease.

b) Awareness creation on MLN disease and its management

In an effort to combat the spread of MLN disease a targeted awareness campaign was done to refresh farmers' knowledge on the management of MLN disease. Disseminating this crucial information to farmers empowered them to adopt proactive measures in their fields, mitigating the risk of disease transmission and promoting overall crop health.

The following approaches were adopted to create awareness.-

i.   Plant Health Rallies
     Before the planting season in 2024, extensive awareness campaigns in form of Plant health rallies were conducted by Trained Technical staff and MITT.

ii. Barazas
     In each of the Seventy -five locations in Barnet County, at least one Baraza was conducted. Printed technical materials (briefs, brochures, flyers, and posters) were distributed and used as teaching aids.

     The Kenya Agricultural and Livestock Research Organization (KALRO) enhanced the campaign by providing access to validated KIAMIS data, empowering county teams with farmers' contacts for ease of scheduling barazas.

iii. Mass media
     Radio programs, with tailored messages for MLN and its management were used to reach a wider audience of farmers. The messages were delivered on local media channels that broadcast in vernacular languages.

c) Diversification with alternative crops

Farmers have been sensitized to embrace crops diversification as an initiative of reducing the viral load in their fields. The aim of this initiative is to diversify agricultural practices and provide farmers with viable crop options that can contribute to a more resilient and sustainable farming systems. Some of the alternative crops are, beans, chickpea, pigeon-peas, cowpeas, sunflower, canola, spring onions, potatoes, pyrethrum, kales, cabbages, indigenous vegetables, sweet potatoes.

d) Training of extension officers

The Ministry of Agriculture and Livestock Development held a training in Naivasha for Extension officers from Bomet County on management of MLND.

e) Opening of seed shop by Kenya Seed Company

The use of fake and uncertified maize seed by farmers in Bomet County exacerbated the spread of MND. Kenya Seed Company opened a seed shop in Bomet County to ensure farmers have access to certified and tolerant maize seed.

2) **Recommend compensation mechanism that should be followed by either the Government of Kenya or any maize seed manufacturer and or reseller found culpable to have compromised on planting seeds quality leading to production losses**

Maize Lethal Necrosis (MLN) is a Transboundary disease that affects all maize crops irrespective of intended end use either as seed, grains or animal feed. Kenya was the first country in Africa to confirm the occurrence of Maize Lethal Necrosis Disease (MLND) in 2011. However, within one year, the disease spread to all East African countries, South-African region and even to West-African region. The disease spread to all maize growing regions of the Country, and all available maize varieties were found susceptible.

The Ministry in the year 2012 rejected a petition for compensation of farmers across the different regions with high MNL disease pressure. This decision was based on the fact that there was no Government Policy on the compensation of farmers for losses accruing from trans boundary and invasive pests outbreaks.

However in 2012, the Ministry of Agriculture and Livestock Development through the Traditional High Value Crops Programme distributed planting materials (Beans, Irish Potatoes, Sweet potatoes, Cassava, Sorghum, and Millet) to farmers affected by the disease.
Due to the various measures put in place by the Government, the severity and spread of the disease declined over time in most regions of the country. There have been sporadic outbreaks of MNL during some seasons but the disease pressure has generally declined.

3) **Recommend measures to be followed by other development stakeholders like Apollo Agriculture to ensure that innocent Kenyan citizens are not alienated, and or victimized in the event of the emergence of similar crop or animal diseases in the future**

Whereas development partners and stakeholders set their criteria to determine the farmers who qualify to receive benefits when they incur losses from emergencies of crop or livestock diseases.

The Government has put in place policies to be adhered to by development partners and stakeholders such as Apollo Agriculture who provide farmers with inputs and other services in the event of the emergence of crop or animal diseases.

4) **Implementation of effective control measures to combat the spread of MLN diseases**

The County Extension Service Providers are encouraged to adopt the Farmer Field School Approach which offers a very effective season-long practical learning experience to the farmers on effective MNL disease control measures. Some of the recommended interventions include:

a) Enforcement of closed seasons for maize

Bomet County is implementing a three-month maize-free period. This approach helps in avoiding continuous maize cultivation or relay planting, with the aim of disrupting the transmission cycle of MLND. This approach involve enforcement and training of farmers on the importance of implementation compliance.

b) Access to high-quality alternative planting materials

Counties to improve access to alternative high-value crop planting materials by bulk order e.g. certified Irish Potato seeds, High-value Nyota Beans, Leafy vegetables for distribution to farmers for planting in 2nd Season.

c) Plant Health Clinics

Counties to mainstream 'Plant Health Clinics' model to offer farming community avenues for seeking pest and disease diagnostic support on a regular basis during market days. Plant Health Clinics initiative was spearheaded by the Ministry of Agriculture with support of CABI in over 20 counties.

d) Demonstrations on tolerant maize varieties

Demonstrations on planting of MNLD-resistant maize varieties. The tolerant maize variety require integration with other IPM measures for better effectiveness. Setting up demonstration plots will enhance the adoption of these resistant varieties.

e) Capacity Building Technical team

MITT to review and update MNLD technical information materials and further Capacity-build county technical teams starting with counties with high disease prevalence.

f) Pesticides use to control MLD

Control of key MLND insect vectors such as aphids and thrips is necessary in order to prevent transmission of MLND viruses. Approved and registered pest control products for control of the insect vectors are being promoted among the farmers and demonstration materials are purchased and distributed to farmers.

5) **Regulation of Maize seed sale to ensure farmers have access to disease-resistant varieties**

f) Pesticides use to control MLD

Control of key MLND insect vectors such as aphids and thrips is necessary in order to prevent transmission of MLND viruses. Approved and registered pest control products for control of the insect vectors are being promoted among the farmers and demonstration materials are purchased and distributed to farmers.

5) Regulation of Maize seed sale to ensure farmers have access to disease-resistant varieties

The Ministry of Agriculture and Livestock Development is responsible for regulating marketing and distribution of maize seed. The Ministry has endeavored to ensure farmers have access to disease resistant varieties.

There are 19 seed varieties which have been tested and released for commercialization to mitigate against MLND. The disease resistant maize varieties available in the market are;

i.   SC 447, SC 445, and SC Duma 441 varieties from Kenya SeeDco Company
ii.   DK777 variety from Monsanto Kenya limited
iii. WE5135, 5139, 5140 varieties from CIMMYT/AATF KALRO - Katumani
iv.   WE6109, WE7118, WE7119 varieties from AATF
v.   MH502 (Taji) Variety from East African Seed Company Limited
vi.   KALZm -H4-301, KALZm -H4-302, and KALZm -H4-303 varieties from KALRO KALRO- Kabete

6) Provision of crop insurance to farmers in the region to mitigate crop losses and provide them with a safety net

The Ministry of Agriculture and Livestock Development is implementing a comprehensive Crop Insurance Program to cushion farmers from losses associated with crop failure due to climatic conditions, floods, pest and disease.

7) Identification and promotion of alternative crops that can be planted in place of maize to ensure farmers and their families have sustainable food security

The Ministry of Agriculture and Livestock Development constituted a Multi-Institutional Technical Team (MITT) with diverse representation from National and regional research institutions (KALRO, ICIPE, CYMMIT); Regulatory agencies (KEPHIS, PCPB); Academia (UoN, Egerton, JKUCAT); Private Sector (Agrochemical industry, Seed Sector) and Plant Protection Officers in State Department for crops Development

The Senator for Bonet County confirmed that there has been marked improvement and a decline in the spread of MLN disease in the County.

Other matters discussed at the meeting include-

a) The Compenstaion of farmers who receiced fake fertilizer. The Ministry informed the Committee that 95% of farmers had been compensated through the distribution of top-dressing fertilizer. Moreover, the Ministry reported prosecuting individual who had been involved in the supply of fake fertilizer. The Ministry also reported plans to operationalise the Fertilizer and Animal Food Stuffs Act by establishing the board

b) Measures to ensure that subsidized fertilizer is available on time to farmers. The Ministry informed the Committee that learning from previous challenges the Ministry has commenced the contracting process early to ensure that fertilizer will be available to farmers at the next planting season.

c) The Committee raised concerns over the golden apple snail they had seen in the Mwea irrigation scheme during a previous Committee activity and urged the Ministry to proactively support the eradication of the pest.

d) The Committee raised concern over the distribution of coconut seedlings to farmers that take a long time to mature. The Ministry informed the Committee that the allocation of fund has been proposed in the FY 2024/24 budget to be allocated through the Commodities Fund for banana, coconut and cashew nut seedlings.

e) The Committee raised concerns on the strict conditions for the export of chillies. KEPHIS advised that the conditions are in place to meet the requirements of export markets.

MIN/SEN/SCA/738/2024-   **ANY OTHER BUSINESS**

There was no other business

MIN/SEN/SCA/739/2024-   **DATE OF NEXT MEETING AND ADJOURNMENT**

The meeting was adjourned at 12:11 p.m.and the next meeting will be by notice.

SIGNED......................................DATE......22/05/24.................

SEN. JAMES KAMU MURANGO
CHAIRPERSON

MINUTES OF THE FIFTY-FIRST SITTING OF THE SENATE STANDING COMMITTEE ON AGRICULTURE, LIVESTOCK AND FISHERIES, HELD ON TUESDAY, 19TH SEPTEMBER 2023 AT FIRST FLOOR BOARDROOM, RED CROSS BUILDING AT 9.00 AM

PRESENT

1. Sen. James Kamau Murango, MP   -   **Chairperson**
2. Sen. Alexander Munyi Mundigi, MP   -   **Vice-Chairperson**
3. Sen. Daniel Kitonga Maanzo, MP   -   Member
4. Sen. Allan Kiprotich Chesang, MP   -   Member
5. Sen. Samson Cherarkey, MP   -   (Friend of the Committee)

ABSENT WITH APOLOGIES

1. Sen. Moses Otieno Kajwang', MP   -   Member
2. Sen. Wahome Wamatinga, MP   -   Member
3. Sen. Enoch Kiio Wambua, CBS, MP,   -   Member
4. Sen. Beth Kalunda Syengo, MP   -   Member
5. Sen. David Wafula Wakoli, MP   -   Member

SECRETARIAT

1. Ms. Caroline Njue   -   Clerk Assistant
2. Mr. Reinhardt Choge   -   Clerk Assistant
3. Ms. Regina Munyao   -   Legal Counsel
4. Ms. Belinda Ogolla   -   Research Officer
5. Ms. Violet Nalianya   -   Media Relations Officer
6. Ms. Rose Ometere   -   Audio Officer

IN – ATTENDANCE

Mr. Hillary Kerich Kiprono   -   Accountant/Petitioner

MIN/SEN/SCA/362/2023-   PRAYER

The Chairperson called the meeting to order at 9.28 a.m. followed by a word of prayer and introductions.

c) Recommend measures to be followed by other development stakeholders like Apollo Agriculture to ensure that innocent Kenyan citizens are not alienated, and or victimized in the event of emergence of similar crop or animal diseases in the future;
d) Implementation of effective control measures to combat the spread of MLN disease;
e) Regulation of Maize seed sale to ensure farmers have access to disease-resistant varieties;
f) Provision of crop insurance to farmers in the region to mitigate crop losses and provide them with a safety net; and
g) Identification and promotion of alternative crops that can be planted in place of maize to ensure farmers and their families have sustainable food security.

The Committee agreed with the Petitioners' prayers especially on the quality of maize seeds and a safety net for farmers in the form of crop insurance and assured the petitioner that the matters raised will be dealt with accordingly.

MIN/SEN/SCA/367/2023-	**CONSIDERATION OF FURTHER AMENDMENTS TO THE AGRICULTURAL AND LIVESTOCK EXTENSION SERVICES BILL, 2022 (SENATE BILLS. NO 12 OF 2022 (COMMITTEE PAPER NO. 49)**

The Committee was taken through the further amendments to the Agricultural and Livestock Extension Services Bi, 2022 (Senate Bills No. 12 of 2022) that emanated from the plenary during the second reading and it resolved to adopt the Amendments as proposed by Sen. Alexander Munyi Mundigi, MP and seconded by Sen. Allan Kiprotich Chesang, MP.

MIN/SEN/SCA/368/2023-	**ANY OTHER BUSINESS**

1. The Committee resolved to prepare the report on the Agriculture and Food Authority AFA (Amendment) Bill, 2023 (Senate Bills No. 13 of 2023) for tabling in October, 2023.
2. The Committee was advised that pursuant to standing order 166 of the Senate Standing Orders, joint sittings only take during mediation when both houses do not agree on some or all of the amendments on a Bill and not before mediation.

MIN/SEN/SCA/369/2023-	**DATE OF NEXT MEETING AND ADJOURNMENT**

The meeting adjourned at 10.51 am and the next meeting will be by notice.

SIGNED: ....DATE: ...3.10.23.....................

SEN. JAMES KAMAU MURANGO, MP
(CHAIRPERSON)

APPENDIX II: PETITION

The Clerk of the Senate
Parliament Buildings
P.O Box 41842 - 00100
NAIROBI
Email: senate.petitions@parliament.go.ke

12 JUN 2023

DIRECTOR LEGISLATIVE
PROCEDURAL SERVI

RE: PETITION TO THE SENATE REGARDING CATASTROPHIC MAIZE DISEASES THAT FARMERS IN BOMET COUNTY HAVE ENDURED FOR THE LAST 12 YEARS

I, the undersigned, a Citizen of the Republic of Kenya and a resident of **Nyangores Ward, Chepalungu Constituency** in the **County of Bomet**, hereby draw the attention of the Senate to the following:

Bomet County is one of the seven most high-potential maize production zones in Kenya, and agriculture serves as the primary economic activity in the county. With a population of 875,689 (2019 census) and a surface area of 1,997.9 km2, Bomet County heavily relies on crops such as maize, beans, and cowpeas. Maize, in particular, plays a crucial role in terms of food and nutrition security as well as income generation

1.   **THAT,** Since September 2011, food security in the county has been severely impacted by a catastrophic maize disease known as Maize Lethal Necrosis (MLN), and households are walking a tightrope putting a square meal on the table, this is even exacerbated by other household budgetary constraints like schools fees, medical expenditure amongst others

>   **1.1 THAT,** The disease which was first identified at the Kipisarwet locality quickly spread to the entire county killing 90% of the planted crop in the year 2012, making maize crop farming an unpopular investment in the region due to losses

>   **1.2 THAT,** To date, no intervention measures have been extended to the residents by either the National Government or the County government. Maize farmers who relied 100% on the maize crop for subsistence and as a cash crop have never had any sensitization on the disease specifically; the negative effects on human and animal health, alternative maize crop varieties to plant, measures to control the spread of the disease and no stringent control measures on maize seeds offered for sale in the region to control on disease recurrence/spread have been put in place

>   **1.3 THAT,** Considering that the disease is a fast spreader, there is a **BIG** risk that other maize-growing regions of Kenya will soon be affected by the disease resulting in 100% maize crop failure in the country and leading to further food insecurity

2.   **THAT,** Other development stakeholders have chosen not to give input loans to farmers in the affected region making them suffer double jeopardy. Currently, Apollo Agriculture, a Fintech organization that enrolls farmers and provides them with inputs as loans, repayable over an agreed period has decided not to provide their services to farmers in the region due to concerns over potential losses .

3.   **THAT,** I have made the best efforts to have these matters addressed by the relevant authorities all of which have failed to give a satisfactory response

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4.   **THAT,** none of these issues raised in this Petition is pending in any court of Law, Constitutional, or any other legal body

WHEREFORE, your humble petitioner prays that the Senate-

Determine the measures the Kenyan Government will implement to provide intervention measures to the rural poor farmers affected by the maize disease in Bomet County, including but not limited to:

1. Stringent supervision of maize farming and investigation into the potential spread of this disease to other crops and its effects on human health

2. Implementation of effective control measures to combat the spread of MLN diseases

3. Regulation of Maize seed sale to ensure farmers have access to disease-resistant varieties

4. Provision of crop insurance to farmers in the region to mitigate crop losses and provide them with a safety net

5. Identification and promotion of alternative crops that can be planted in place of maize to ensure farmers and their families have sustainable food security

Dated this **8th** day of **JUNE 2023**

NO.	NAME	ADDRESS	ID. No.	SIGNATURE
1.	Kerich Kipronoh Hillary	P.o Box 19-20400 Bomet	21014640	

APPENDIX III:
SUBMISSIONS FROM
MoALD

APPENDIX III:
SUBMISSIONS FROM
MoALD

MINISTRY OF AGRICULTURE AND LIVESTOCK DEVELOPMENT

PETITION REGARDING CATASTROPHIC MAIZE DISEASE THAT FARMERS IN BOMET HAVE ENDURED FOR 12 YEARS

BY

Dr Kipronoh Ronoh P
PRINCIPAL SECRETARY

MAY 2024

Introduction

Bomet County relies on maize and cowpeas production for food security. The county has high potential for maize production. Maize production contributes significantly to food and nutritional security, and generation of income to about 95% of the residents.

Food security in the County has been affected negatively by Maize Lethal Necrosis (MLN) disease that was first identified at Kipisarwet area in 2011. The disease has a potential to cause 100% maize crop failure. The Ministry and the County Government of Bomet has employed several strategies and interventions to manage the spread of the disease in the Country.

1. Stringent supervision of maize farming and investigation into the potential spread of this disease to other crops and its effects on human and animal health

Response

Agriculture production is a function of County Governments. However the Ministry of Agriculture and Livestock Development has been collaborating the County Governments in addressing challenges affecting development of the agriculture sector.

Pest and disease incidences have negative effects on crop production. Maize Lethal Necrosis Disease (MLND) is a serious disease of maize that has affected farmers in Bomet County. The disease also has effects on human and livestock health.

To minimize the negative impact of the MLND disease, the Ministry in collaboration with County Governments have done the following.

Formation of Multi-Institutional Technical Team

The Ministry of Agriculture and Livestock Development in collaboration with Bomet County constituted a Multi-Institutional Technical Team (MITT) to address Maize Lethal Necrosis Disease. The team is comprised of wide range of stakeholders such as National and regional research institutions (KALRO, ICIPE, CYMMIT); Regulatory agencies (KEPHIS, PCPB); Academia (UoN, Egerton, JKUCAT); Private Sector (Agrochemical industry, Seed Sector) and Plant Protection Officers in State Department for crops Development.

The team was charged with the responsibility of investigating the spread of the disease as well as giving recommendations on how to control and manage the disease.

Awareness creation on MLND and its management

In an effort to combat the spread of MLND, a targeted awareness campaign was done to refresh farmers' knowledge on management of MLND.

By disseminating this crucial information, farmers were empowered to adopt proactive measures in their fields, mitigating the risk of disease transmission and promoting overall crop health. The following approaches have been adopted to create awareness.

i. Plant Health Rallies

Before the planting season in 2024, extensive awareness campaigns in form of Plant health rallies were conducted by Trained Technical staff and MITT

members as a form of mass extension campaign intended to reach a large number of farmers who had suffered the effect of MLND.

ii. Barazas

In each of the Seventy -five locations in Bomet County, at least one Baraza was conducted. Printed technical materials (briefs, brochures, flyers, and posters) were distributed and used as teaching aids.

The Kenya Agricultural and Livestock Research Organization (KALRO) enhanced the campaign by providing access to validated KIAMIS data, empowering county teams with farmers' contacts for ease of scheduling barazas.

iii. Mass media

Radio programs, with tailored messages for MLND and its management were used to reach a wider audience of farmers. The messages was delivered on local media channels that broadcast in vernacular languages.

Diversification with alternative crops

Farmers have been sensitized to embrace crops diversification as an initiative of reducing the viral load in their fields. The aim of this initiative is to diversify agricultural practices and provide farmers with viable crop options that can contribute to a more resilient and sustainable farming systems.

Some of the alternative crops are, beans, chickpea, pigeon-peas, cowpeas, sunflower, canola, spring onions, potatoes, pyrethrum, kales, cabbages, indigenous vegetables, sweet potatoes.

Training of extension officer

4

The Ministry of Agriculture and Livestock Development held a training in Naivasha for Extension officers from Bomet County on management of MLND.

Opening of seed shop by Kenya Seed Company

The use of fake and uncertified maize seed by farmers in Bomet County exacerbated the spread of MND. Kenya Seed Company opened a seed shop in Bomet County to ensure farmers have access to certified and tolerant maize seed.

2. Recommend compensation mechanism that should be followed by either the Government of Kenya or any maize seed manufacturer and or reseller found culpable to have compromised on planting seeds quality leading to production losses

Response

Maize Lethal Necrosis (MLN) is a Trans boundary disease that affects all maize crops irrespective of intended end use either as seed, grains or animal feed.

Kenya was the first country in Africa to confirm occurrence of Maize Lethal Necrosis Disease in 2011. However, within a span of one years, the disease

spread to cover all East African countries, South- African region and even to West-African region.

The disease spread to all maize growing regions of the Country, and all available maize varieties were found susceptible.

The Ministry in the year 2012 rejected a petition on compensation of farmers across the different regions with high MNL disease pressure.

This decision was based on the fact that there was no Government Policy on compensation of farmers for losses accruing from trans boundary and invasive pests outbreaks.

However in 2012, the Ministry of Agriculture and Livestock Development through Traditional High Value Crops Programme distributed planting materials (Beans, Irish Potatoes, Sweet potatoes, Cassava, Sorghum, and Millet) to farmers affected by the disease.

Due to the various measures put in place by the Government, the severity and spread of the disease declined overtime in most regions of the country. There have been sporadic outbreaks of MNLD during some seasons but the disease pressure has generally declined.

3. Recommend measures to be followed by other development stakeholders like Apollo Agriculture to ensure that innocent Kenyan citizens are not alienated, and or victimized in the event of emergence of similar crop or animal diseases in the future

Response

Development partners and stakeholders set their criteria to determine the farmers who qualify to receive benefits when they incur losses from emergency of crop or livestock diseases.

The Government has put in place policies to be adhered to by development partners and stakeholders such as Apollo Agriculture who provide farmers with inputs and other services in the event of emergence of crop or animal diseases.

4. Implementation of effective control measures to combat the spread of MLN diseases

Response

The County Extension Service Providers are encouraged to adopt Farmer Field School Approach which offers a very effective season-long practical learning experience to the farmers on effective MNLD control measures. Some of recommended interventions include:

i) Enforcement of closed seasons for maize

In Bomet County is implementing a three-month maize-free period. This approach helps in avoiding continuous maize cultivation or relay planting, with the aim of disrupting the transmission cycle of MLND. This approach involve enforcement and training of farmers on the importance of implementation compliance.

ii) Access to high quality alternative planting materials

Counties to improve access to alternative high value crop planting materials by bulk order e.g. certified Irish Potato seeds, High value Nyota Beans, Leafy vegetables for distribution to farmers for planting in 2nd Season.

iii) Plant Health Clinics

Counties to mainstream 'Plant Health Clinics' model to offer farming community avenues for seeking pest and diseases diagnostic support on regular basis during market days. Plant Health Clinics initiative was spearheaded by Ministry of Agriculture with support of CABI in over 20 counties.

iv) Demonstrations on tolerant maize varieties

Demonstrations on planting of MNLD resistant maize varieties. The tolerant maize variety require integration with other IPM measures for better effectiveness. Setting up demonstration plots will enhance adoption of these resistant varieties.

v) Capacity Building Technical team

MITT to review and update MNLD technical information materials and further Capacity build county technical teams starting with counties with high disease prevalence.

vi) Pesticide used to control MLD

Control of key MLND insect vectors such as aphids and thrips is necessary in order to prevent transmission of MLND viruses. Approved and registered pest control products for control of the insect vectors are being promoted among the farmers and demonstration materials purchased and distributed to farmers. The pesticides are shown in table 1.

Table 1. Registered pesticides for control of maize thrips in Kenya

PRODUCT NAME	ACTIVE INGREDIENT
DUDUTHRIN 1.7 EC Emulsifiable Concentrate	Lambda-cyhalothrin 17.5g/L
XPAND MAX 92% SG Water Soluble Granules	Acephate 920g/kg
LOTUS 75% SP Soluble Powder	Acephate 750 g/kg
UMEME TOP 5 EC Emulsifiable Concentrate	Lambda-cyhalothrin 50 g/L
RADIANT 120 SC Suspension Concentrate	Spinetoram 120g/L
THUNDER OD 145	Imidacloprid 100g/L + Beta-cyfluthrin 45g/L
SHIELD 600 FS Flowable concentrate for seed treatment	Imidacloprid 600g/L

5. Regulation of Maize seed sale to ensure farmers have access to disease-resistant varieties

Response.

The Ministry of Agriculture and Livestock Development is responsible for regulating marketing and distribution of maize seed. The Ministry has endeavored to ensure farmers have access to disease resistant varieties.

There are 19 seed varieties which have been tested and released for commercialization to mitigate against MLND. The disease resistant maize varieties available in the market are;

- SC 447, SC 445, and SC Duma 441 varieties from Kenya SeeDco Company
- DK777 variety from Monsanto Kenya limited
- WE5135, 5139, 5140 varieties from CIMMYT/AATF KALRO – Katumani
- WE6109, WE7118, WE7119 varieties from AATF
- MH502 (Taji) Variety from East African Seed Company Limited
- KALZm -H4-301, KALZm -H4-302, and KALZm -H4-303 varieties from KALRO KALRO- Kabete

6. Provision of crop insurance to farmers in the region to mitigate crop losses and provide them with a safety net

The Ministry of Agriculture and Livestock Development is implementing a comprehensive Crop Insurance Program to cushion farmers from losses

associated with crop failure due to climatic conditions, floods, pest and disease.

7. Identification and promotion of alternative crops that can be planted in place of maize to ensure farmers and their families have sustainable food security

Response

The Ministry of Agriculture and Livestock Development constituted a Multi-Institutional Technical Team (MITT) with diverse representation from National and regional research institutions (KALRO, ICIPE, CYMMIT); Regulatory agencies (KEPHIS, PCPB); Academia (UoN, Egerton, JKUCAT); Private Sector (Agrochemical industry, Seed Sector) and Plant Protection Officers in State Department for crops Development

In July 2012, the MITT and County teams identified the following high value commercial crops that farmers could alternate with maize in 2nd season.

Table 2. Alternative high value crops

Area	Alternative high value crops
Embu	Cabbages, Irish potatoes, Carrots, Kales ; Sweet potatoes, Field Beans, Climbing Beans
Meru	Beans, Dolichos, Bananas, Pawpaws, Mangoes, sorghums, millets, pigeon peas, green grams, sweet potatoes
Nakuru	Irish potatoes, Sweet potato, Pyrethrum, Garden Peas, Shallots, Kales, Cabbages, Climbing beans, Livestock fodder (Lucerne)
Narok	Wheat, sunflower, potato, Garden peas, sorghum
Bomet	Potato, Beans, Sorghum, Fodder for dairy animals
Kisii	Beans, finger millets, bananas, sweet potato
Kakamega	Beans, bananas, sweet potato, sorghum
Bungoma	Sugarcane, beans, finger millet
Uasin Gishu	Beans, millets
Machakos , Makueni	Beans, sorghums, millets, Sweet potatoes, mangoes

Date......20.5.24

Dr Kipronoh Ronoh P,

PRINCIPAL SECRETARY

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APPENDIX IV: SUBMISSION FROM KALRO

KENYA AGRICULTURAL AND LIVESTOCK RESEARCH ORGANIZATION

SUBMISSION TO THE SENATE STANDING COMMITTEE ON AGRICULTURE, LIVESTOCK AND FISHERIES IN RESPONSE TO THE PETITION ON CATASTROPHIC SPREAD OF MAIZE LETHAL NECROSIS DISEASE IN BOMET COUNTY

1. INTRODUCTION

We acknowledge receipt of your letter dated 16th May, 2024 inviting KALRO to a meeting with the Standing Committee on Agriculture to deliberate on the petition submitted by Mr. Kerich Kipronoh Hillary a resident of Nyangores Ward, Chepalungu Constituency, Bomet County. Through the said Petition, the Petitioner states that since 2011 the residents of Bomet County have faced severe maize production challenges due to the wide spread of Maize Lethal Necrosis.

Among the issues raised in the Petition for deliberation include;

1. That no intervention measures have been extended to the residents of Bomet County by either the National or County Government.
2. That maize farmers in the County have never been sensitized on the disease specifically on matters relating to the negative effects on human and animal health, alternative crop varieties to plant, measures to control the disease and that no stringent control measures on maize seeds offered for sale in the region to control recurrence of the disease have been put in place.
3. There is risk of the disease spreading to other maize growing regions of Kenya resulting in 100% maize crop failure in the Country leading to further food security.

The Petitioner therein seeks that the Senate recommend intervention mentions to the Kenyan Government which include but are not limited to;

1. Stringent supervision of maize farming and investigation into the potential spread of the disease to other crops and its effect to animal and human health.
2. Implementation of effective control measures to combat the spread of MLN diseases.
3. Regulation of maize seed sale to ensure farmers have access to disease resistant varieties.

4. Identification and promotion of alternative crops that can be planted in place of maize to ensure farmers and their families have sustainable food security.

2. KALRO's SUBMISION

Having read through the Petition, KALRO seeks to respond to the issues arising as follows:

I.   FIRST OCCURRENCE OF MLND IN KENYA

Maize lethal necrosis disease (MLND) was first reported in September 2011 as an unfamiliar disease in the low altitude zones of Bomet County (Longisa Division, around 1900m above sea level) affecting about 200 Ha of the second season maize crop. The effects of the disease were sudden; devastating and could not be explained. The cause of the problem was unknown. Local farmers called it 'Koroito', which is the vernacular name for plague. By the end of 2011 the disease had spread to the higher altitudes of Bomet (2100m asl), the neighboring Chepalungu, Narok South, Narok North and Naivasha sub-counties. In 2012 the disease was reported in all maize growing regions in the country except North Eastern.

II.   SYMPTOMS OF MLND

The disease expression shows a diverse range of symptoms that can be observed on plants as early as 2 weeks after germination up to cob formation stage. The affected maize plants show bright yellowing of the leaves often with dark green patches. The disease symptoms are often seen starting with the youngest leaves. The yellowing leaves gradually dry up leading to death of the entire plants, giving a blighted appearance of the crop. Additionally, Tassels appear to have no pollen. The outer husks covering the cob dry prematurely, while the grains inside are still milky and the rest of plant is green. There may also be partial grain or no grain filling in the cob.

III. EARLY AND SUBSEQUENT ACTIONS TAKEN

a) Determination of the cause and spread of MLN

As reports of occurrence of the unfamiliar disease continued being received, the Ministry of Agriculture constituted a Multi-Institutional Technical Team (MITT) comprising the Plant Protection and Food Security Directorate (PPFSD, then PPSD), the Kenya Agricultural Research Institute (KALRO, then KARI), Kenya Plant Health Inspectorate Service (KEPHIS) and other institutions to undertake field assessment, collect samples for laboratory analysis for identification of the causative pathogens, and come up with control and management protocol.

Diseased materials collected in February-March 2012 were subjected to laboratory analysis locally and abroad. The confirmed results indicated viruses as the disease-causing agents. KALRO, Ohio State University (USA), through CIMMYT identified maize chlorotic mottle virus (MCMV). A combination of MCMV and the sugarcane mosaic virus (SCMV) was detected by the Food and Environment Research Agency (FERA), UK through CABI.

Maize Lethal Necrosis disease results from maize plants being attacked at the same time by maize chlorotic mottle virus (MCMV) and sugarcane mosaic virus (SCMV) or any of several potyviruses including maize dwarf mosaic virus (MDMV) and wheat streak mosaic virus (WSMV). The principal agents responsible for spread of the viruses are vectors (thrips and aphids) and infected seeds.

b) Development and dissemination of information materials

The Multi-Institutional Technical Team (MITT) developed posters and brochures containing information on identification and management options for MLN disease. The materials were largely developed with financial support through collaborative projects.

c) Training of agricultural extension staff and other stakeholders

Training forums were organized by teams implementing various projects for agricultural extension staff in project target counties. The forums made use of training slides and a training manual on identification and management of MLN disease.

d) Stakeholder sensitization and awareness creation

Through project initiatives, the following awareness creation activities have been undertaken in selected counties and nationally:

i.   Press release by the Cabinet Secretary Hon. Felix Kosgei, Ministry of Agriculture, Livestock and Fisheries (2014).

ii.   Plant health rallies (PHRs) on MLN in **Bomet**, Uasin Gishu and Kilifi Counties. For Bomet, the PHRs were conducted at Kembu, Chemaner, Choronok, Merigi, Tembwo, Ndanai, Chepostuyet, Singiroi and Sigor in November 2015. Reports, photographs and video clips are available.

iii. Radio talk shows on the Kenya Broadcasting Corporation (KBC) – *Mali Shambani* Program. The approximately one-hour radio programme is available.

e) Breeding and deployment of MLN-tolerant maize varieties

The Kenya Agricultural and Livestock Research Organization (KALRO) and International Maize and Wheat Improvement Center (CIMMYT) with support from the Bill & Melinda Gates Foundation and the Syngenta Foundation for Sustainable Agriculture established an MLN-Screening site on KALRO's land at the Dairy Research Institute (DRI), Naivasha. The site has been in operation since 2013 and has been used in the evaluation of maize germplasm from multinationals, national seed companies and KALRO, leading to development and release of over 16 MLN-tolerant maize varieties in Kenya.

The following are among the varieties that are already in the market: DK777 (Bayer), H6506 (KSC), SC439, SC441, SC447 (Agri-seedco), Tumaini (Ultravetis) and WH301.

Further work is being undertaken to fast-track the development and deployment of additional MLN-tolerant varieties through modern tools and technologies such as Genome editing (GEd) technology, with anticipation of shortened breeding-to-release durations, without altering other important traits in already released/commercial varieties. This is being explored by KALRO in collaboration with Corteva and CIMMYT.

IV. RECOMMENDATIONS FOR SUSTAINABLE MANAGEMENT OF MAIZE LETHAL NECROSIS DISEASE

Noting that a lot of progress has been made in the development and dissemination of technologies, innovations and management practices to mitigate the effects of maize lethal necrosis disease, sustained onslaught on the disease is the key to success.

This requires continued sensitization of farmers by government and non-governmental agencies through various mechanisms and channels of communication. County government agricultural extension services and their partner institutions come in handy in this matter. Such efforts should further be strengthened through capacity building of extension service providers and farmers as well as by development and dissemination of improvers technologies, innovations and management practices by research agencies.

The measures outlined below should be applied in an integrated approach and in a persistent manner since they have been instrumental in suppressing maize lethal necrosis disease in the past.

1. Choice of maize seed for planting

a) Use suitable certified seed of tolerant maize varieties.
b) Avoid using home saved seed from previously infested MLN fields or from unknown source e.g. from local market - certified seeds are supposed to be free from MLN viruses and are also treated with protective insecticides.

2. Timing and site selection for maize planting

a) Plant early at the onset of rains and ensure proper soil fertility is maintained.
b) Avoid planting your maize crop next to sorghum, millet, napier grass, sugarcane.

3. Cultural practices for maize crops

a) Avoid continuous planting of maize crop to prevent build-up of insect vectors and the possible persistence of MLN viruses as happens when a field/areas has different stages of maize crops.
b) Practise strict crop rotation on land that had severe MLN disease; crops such as potatoes, legumes, vegetables or other non-grass crops can be considered.
c) Practise closed season for maize - skip growing of maize in following season if the previous crop season had a high MLN prevalence in a particular locality (village or zone).
d) Intercrop maize with potatoes, beans, groundnuts, soybean and vegetables especially during second season rains; this provides alternative produce.

4. Field sanitation practices for maize crops

a) Practise roguing – uproot and dispose of maize plants with MLN disease symptoms as soon as they are seen. Total destruction of a crop may be considered if the severity is very high.
b) Keep your crop and the garden boundaries free of weeds since they may be alternative hosts to vectors of MLN viruses.
c) Avoid using crop remains from severely MLN-infested fields as mulch or in trash lines; collect and destroy such trash (e.g. by burning).

5. Control vectors of MLN viruses in maize crops

a) Control insect pests such as thrips and aphids in maize crops since they can transmit MLN viruses. Blue and yellow colour sticky traps or insecticides can be applied as per manufacturers' instructions (refer to PCPB website for registered products, https://www.pcpb.go.ke/crops/).
b) For effective control of pests, do regular scouting in maize crop fields to determine the need to apply control measures - start to observe your fields for pests as early as possible, preferably 2 weeks after maize emergence.

V: PROPOSED ACTION PLAN FOR MANAGEMENT OF MAIZE LETHAL NECROSIS DISEASE

With the guidance of the Principal Secretary for Agriculture, Dr. Paul Rono, an action plan for management of maize lethal necrosis (MLN) in Bomet County was developed in December 2023. The plan proposes to implement the following key activities:

- Deployment of MLN tolerant Seed
- Closed Season for Maize
- Disease and vector monitoring and control
- Awareness creation on MLN and its management
  - Plant Health Rallies
  - Barazas
  - Mass media
- Establishment of a community of practice within the County
- Diversification with alternative crops

Support for implementation of the plan is sought under the leadership of the Plant Protection and Food Safety Directorate (PP&FSD).

The action plan was developed by a joint team with representatives from the State Department for Agriculture and Bomet County supported by the Multi-Institutional Technical Team (MITT) on plant health with representation from PP&FSD, Pest Control Products Board (PCPB), Kenya Agricultural and Livestock Research Organization (KALRO), Kenya Plant Health Inspectorate Service (KEPHIS), University of Nairobi (UoN), Centre for Agriculture and Biosciences International (CABI), International Maize and Wheat Improvement Center (CIMMYT), International Centre of Insect Physiology and Ecology (icipe) and an expert from the private sector.

VI. CONCLUSION

In conclusion, it is our opinion that indeed the government has made significant efforts towards eradicating Maize Lethal Necrosis in Bomet and other Counties and the said efforts have yielded promising results. This as demonstrated above has been made possible through strategic initiatives, research investments, and collaboration with stakeholders.
However, continuous management and proactive measures are essential to achieve total eradication. Sustained vigilance and adaptation to emerging challenges will ensure the long-term health and productivity of maize crops, securing food security and economic stability for Bomet County and other the affected regions.

APPENDIX V: SUBMISSIONS FROM KEPHIS

Our Ref: KEPHIS/HQ/3/59 Vol. 20(37)   **Date**: 22nd May, 2024

The Clerk of the Senate
Parliament Buildings
P.O. Box 41842-00100
NAIROBI
Email: senate.petitions@parliamnent.go.ke

Attn: Ms Gloria Wawira
       Clerk Assistant
       Email: Gloria.wawira@parliament.go.ke

Dear Mr. Nyegenye, CBS,

RE: INVITATION TO A MEETING OF THE STANDING COMMITTEE ON AGRICULTURE

Reference is made to your letter **Ref. SEN/DSE/SCA/CORR/05/2024/155** dated **16th May, 2024** on the above subject.

Kenya Plant Health Inspectorate Service (KEPHIS) is a state corporation in the Ministry of Agriculture and Livestock Development with the mandate of assuring plant health and quality of agricultural inputs and produce.

This is to confirm my attendance and also to forward the Brief in regard to the petition.

Yours Sincerely,

PROF. THEOPHILUS M. MUTUI, PHD
MANAGING DIRECTOR

BRIEF ON MLND AND KEPHIS RESPONSE TO THE PETITION TO THE SENATE REGARDING MAIZE LETHAL NECROSIS DISEASE IN BOMET COUNTY

1 Background information

1.1 KEPHIS is the competent authority in seed and phytosanitary certification.

Maize Lethal Necrosis disease (MLND) is a result of a combination of two viruses Maize chlorotic mottle virus (MCMV) and any of the potyvirus e.g. the *Sugar Cane Mosaic Virus*, *Wheat Streak Mosaic Virus* or *Maize Dwarf Mosaic Virus*. The double infection of the two viruses gives rise to what is known as Maize Lethal Necrosis disease (MLND). In Kenya it has been reported that the double infection is caused by *Maize Chlorotic Mottle Virus* (MCMV) and the *Sugar Cane Mosaic Virus*.

1.2 Vectors of the disease and mode of transmission:

MLND is mainly spread by vector, transmitting the disease from plant to plant and field to field. The most common vectors are maize **thrips and aphids**. Thrips vectors maize chlorotic mottle virus and sugarcane mosaic virus is vectored by aphids. The disease can also be transmitted mechanically and through seed.

The disease is more prevalent in areas where farmers practice relay cropping, where vectors carry the viruses from on crop to the next. This is a common practice in South Rift, where Bomet is located nad farmers are always encouraged to have a break/closed season (avoid relay cropping of maize). The impact of the disease is not much in North Rift as there is usually a break from one season to the next.

1.3 History of introduction of the disease:

In Kenya the first occurrence of unfamiliar maize disease was first reported in September 2011 in parts of Bomet County (Longisa Division) affecting about 200 Ha of the second season maize crop. The effects of the disease were sudden; devastating and the cause was yet unknown. Local farmers called it 'Koroito', which is the vernacular name for plague. By the end of 2011 the disease had spread to the higher altitudes of Bomet (2100 m a.s.l), the neighbouring Chepalungu, Narok South, Narok North and Naivasha sub-counties. By 2012 the disease had been reported in all maize growing regions in the country except North Eastern.

The initial symptoms of the disease were varied, but apparently restricted to the leaf, stem and ears. Typically, early leaf symptoms were mottling and chlorosis that progressed to give some deformity and then extensive necrosis. Stems were also seen to show deformity, foliar infection was often associated with the leading growth, with early formed leaves remaining green. For plants with foliar or stem infection, grain filling was shown to be markedly reduced. In affected fields, infection rates approaching 100% were typical and yields were severely affected.

1.4 Identification done by FERA:

Initial attempts at diagnosis using traditional approaches failed to identify any potential pathogens in the diseased plant material (fungal, bacterial or viral) and as a result the Next-Generation Sequencing (NGS) approach using 454-sequencing was deployed. This work was performed at the Food and Environment Research Agency (FERA) labs in the UK, in collaboration with CAB International (CABI). The sequencing highlighted the presence of *Maize chlorotic mottle virus* (MCMV) and a variant isolate of *Sugarcane mosaic virus* (SCMV), a combination of viruses known to cause Maize Lethal Necrosis Disease (MLND). Over 90% of both viral genome sequences were obtained, allowing strain characterization and the development of specific real-time PCR assays which were used to confirm the presence of the virus in material with symptoms from six different fields in two different regions of Kenya. The developed real-time PCR assays were later validated and adopted for use at KEPHIS for routine diagnosis of maize seed samples.

1.5 Yield loses experienced: The yield losses due to MLN is estimated to be 50–100 % in Kenya (Mahuku et al., 2015; De Groote et al., 2016 and Mwatuni et al 2020).

2 Interventions

Awareness creation: from the initial period

Surveillances carried out

Seed certification and mandatory seed testing for all maize seed lots grown in Kenya and imported.

Meeting giving a decision for testing of all seed lots for MLND (minutes) and mandatory seed treatment with systemic insecticides.

Release of resistant varieties.

Maize agronomic practices – farmers advised to observe a break season to avoid carry over of disease from one season to the next.

Stringent control measures on seed maize offered for sale.
Certification for MLND, post control, inspection tolerances at field level for seed crops

3 Confirm distribution of the disease

Severity in the different counties:-

KEPHIS is aware of the status of the Maize Lethal Necrosis Disease (MLND) in the country including Bomet County (Maize survey report 2023, Maize survery report 2022, Maize survey report 2018).

Interventions to prevent spread to other maize producing counties:-....

4. Communication

Has KEPHIS had communication to the seed growers on MLND
Communication to famers in the different production areas
Training for seed producers
Awareness creation to famers

5. Response to Petitioner's Prayers

1. Recommend compensation mechanism that should be followed by either the Government of Kenya or any maize seed manufacturer and or reseller found culpable to have compromised on planting seeds quality leading to production losses. Section 10 of the Seeds and Plant Varieties Act Cap 326 provides for offences, penalties and fines related to seed quality. Since MLND is established in the country, prevalent in the maize growing areas and the vectors are naturally present, the risk and opportunity for infection of maize crops is unavoidable. Use of a **closed season** has been identified as a key intervention.

2. Implementation of effective control measures to combat the spread of MLND

   a) Kephis is already implementing the following control measure
   - Seed certification – field inspections and rejection of crops showning disease symptoms
   - Management of vectors (thrips, aphids)
   - Testing of all seed lots produced locally and those imported for the viruses. Any seed testing positive for any of the viruses is not authorized for sale.
   - Surveillance and monitoring

   b) KEPHIS encourages farmers to practice a **Closed season**

3. Regulation of maize seed sale to ensure farmers have access to disease-resistant varieties. KEPHIS has tested and facilitated release of 16 MLN tolerant maize varieties developed by various breeders, Some are already in the market and others are at different stages of seed multiplication.

4. Identification and promotion of alternative crops that can be planted in place of maize to ensure farmers and their families have sustainable food security
   KEPHIS has been promoting avocado production as an alternative the suitable areas including Bomet Country for export market.

APPENDIX VI:
SUBMISSIONS FROM PCPB

PEST CONTROL PRODUCT BOARD

BRIEF IN RESPONSE TO THE CLERK OF THE SENATE
A PETITION REGARDING CATASTROPHIC MAIZE DISEASES THAT FARMERS IN BOMET COUNTY HAVE ENDURED FOR THE LAST 12 YEARS

Reference is made to the letter from the office of the clerk of the Senate Ref SEN/DSEC/SCA/CORR/11/10/2023/143 on the above subject dated 12th October, 2023 and the follow-up letter on the same from the Ministry.

Maize lethal necrosis disease (MLND) was first reported in Kenya in Bomet County in September 2011. Within a span of one year, the disease had been reported and confirmed in Eastern, Rift Valley, Nyanza, Western, Nairobi and Central regions. The MLN disease is caused by a combination of two viruses; the *Sugarcane mosaic virus* (SCMV) and *Maize chlorotic mottle virus* (MCMV). The transmission of MCMV can be mechanical, by several insect vectors (maize thrips, maize rootworms, leaf beetles and leaf hoppers) and by seeds. The SCMV is transmitted by aphids. Continuous maize production in a field was observed to greatly increase the incidence of the viruses and vectors. Infected maize plants show severe symptoms that result in the cobs not having grains or rotten grains, thus drastically affecting yields.

Soon after MLND was reported, the government set up a Multi-disciplinary technical team to assess the situation and come up with ways of managing the problem. A survey on MLND by the Multi-disciplinary technical team in mid - July 2012 observed the presence of the disease in most maize growing areas in Kenya. The multi-disciplinary technical team was composed of Ministry of Agriculture, Livestock And Fisheries (MOALF-PPSD), Kenya Agricultural Research Institute, (now KALRO), Kenya Plant Health Inspectorate Service (KEPHIS), Pest Control Products Board (PCPB), University Of Nairobi (UON) and the International Centre For Insect Pest Ecology (Icipe)

Being a viral disease, there are no pest control products known to control the virus directly. However, from literature, the viruses can be transmitted by several insect vectors, through mechanical transmission and by seeds. The potential common vectors identified in Kenya are:- maize thrips, maize rootworms, leaf beetles aphids and leaf hoppers.

The Pest Control Product Board, being a Statutory body in charge of regulation of Pest Control Products in Kenya carried out efficacy trials at Longisa, Bomet County and Sunripe farm in Naivasha in October 2012 to 2013 on a number of pest control products in

collaboration with the Agrochemical industry and Kenya seed Company to manage the vectors. Twenty one (21) products were tested in various application regimes including seed dressing and foliar application on maize.

Seed dressing with some pesticides followed with foliar application delayed disease manifestation and reduced disease incidence and severity. Following various trials, one product, PONCHO FS 600 Flowable concentrate containing Clothianidin 600g/L was registered by PCPB as a Seed dresser insecticide for the control of Aphids in Maize followed by foliar spray with Thunder OD 145 for Thrips control for reduction of Maize Lethal Necrosis Disease (MLND). The details of the products are available to the public through the PCPB website, https://www.pcpb.go.ke.

The multi-disciplinary technical team recommended various options of managing MLN and preventing spread to new locations. They recommended *integrated pest management practices encompassing cultural control such as closed season, rogueing infected plants, practicing field hygiene, crop rotation and crop diversification, vector control using seed treatment followed by foliar sprays and host plant resistance.*

The multi-disciplinary technical team also developed a training manual for Maize Lethal necrosis in 2013 to guide extension staff and other service providers. The Ministry, through the MITT, implemented various interventions to mitigate against this disease. Although the incidence and severity of the MLND was noted to have reduced significantly following the proposed management interventions, there has been a recent resurgence of MLND in Bomet County and other areas.

A workshop on enhancing management of Maize Lethal Necrosis (MLN) Disease took place from 4th to 8th December 2023 at Dairy Training Institute, Naivasha. The workshop was attended by members of the Multi- Institutional Technical Team (MITT) including PCPB, KEPHIS, KALRO, PP&FSD, University of Nairobi, CABI, CYMMIT, private sector and ICIPE. Agricultural officers from Bomet County were also present.

1. Technical materials for awareness creation were developed i.e. a technical brief, a poster and a flier.
2. Agricultural extension officers from Bomet County were trained.
3. An action plan for management of MLN in Bomet County was developed.

PEST CONTROL PRODUCT BOARD

A public launch of interventions took place on Tuesday, 16th January 2024 in Bomet County, Bomet town where PCPB participated. Hon. Franklin Linturi, the Cabinet Secretary, Ministry of Agriculture and Livestock Development was the chief guest in the function. The function was attended by the PS, state department for crops, the Bomet County Governor, local MPs, County Commissioner, CEOs of various agencies in the Ministry of agriculture, chairpersons of the agencies and farmers.

Three activities took place during the function:
- Launching of MLND management initiative in the county. Kenya Seed Company unveiled a new maize variety that is tolerant to MNLD which will help the farmers fight the disease. All the MITT members showcased different technologies and approaches in MNLD management. PCPB has registered one product (PONCHO FS 600) for seed dressing against thrips and aphids and one for foliar application (Thunder OD 145).
- Opening of Kenya Seed branch in Bomet County and flagging off seed distribution in the county. The opening of the Kenya Seed Company, Bomet branch will reduce sale of fake maize seeds in the county.
- Flagging off of four mobile maize driers to different wards in Bomet County. The driers will help the farmers in management of post-harvest losses and aflatoxin poisoning in maize thus improving food safety.

PCPB was represented by the CEO and technical staff in the function. The attendants were taken through the following areas by PCPB:
- The pesticides registered for management of MLND
- Reading and interpretation of pesticides label
- How to access PCPB website and how to search for different kinds of information
- How to recognize illegal pesticides and mitigation measures

Fredrick N. Muchiri
CHIEF EXECUTIVE/SECRETARY

APPENDIX VII:
SUBMISSIONS FROM
PETITIONER

A PRESENTATION TO THE KENYAN SENATE SELECT COMMITTEE ON AGRICULTURE
ON THE IMPACT OF
MAIZE LETHAL NECROSIS DISEASE
A CASE FOR BOMET COUNTY, REPUBLIC OF KENYA

INTRODUCTION

Bomet County covers a surface area of 1,997 km2, KM² and has a population of 875,689 (2019 census). The county is divided into 5 administrative regions, namely; Bomet East, Chebalungu, Konoin, Bomet Central, and Sotik Sub counties. The land is entirely arable and suitable for Agricultural production. Farmers in the County heavily rely on maize, beans, and cowpea production for their food security. Maize, in particular, plays a crucial role in terms of food and nutrition security as well as income generation for up to 95% of the residents

Since September 2011, food security in the county has been severely impacted by a catastrophic maize disease known as **Maize Lethal Necrosis (MLN)**, and households are walking a tightrope to put a square meal on the table, this is even exacerbated by other household budgetary constraints like schools fees, medical expenditure amongst others. The disease, which was first identified at the Kipisarwet locality, quickly spread to the entire county, killing 90% of the planted crop in the year 2012, making maize crop farming an unpopular investment in the region due to losses. To date, no intervention measures have been extended to the residents by the National Government or the County government. Maize farmers who relied 100% on the maize crop for subsistence and as a cash crop have never had any sensitization on the disease specifically;

- Its negative effects on human and animal health,
- Alternative maize crop varieties to plant,
- Measures to control the spread of the disease and
- No stringent control measures on maize seeds offered for sale in the region to control disease recurrence/spread have been put in place

CHALLENGE

Being a resident of the county and during my interaction with the farmers, I found a dire situation where farmers could no longer plant hybrid maize seeds supplied by the Kenya Seed Company and sold by Agro-dealers in the county. A farmer who plants the seeds will find that his/her crops develop a yellow pigmentation at the age of between 2-3 months, The maize then becomes stunted in growth and, on some occasions, starts to rot, leaving the farmer counting losses.
Farmers then resort to purchasing expensive maize from other regions to feed their families, creating an extra cost for households that are also facing the burden of high medical fees, and high school fees, amongst other household expenses.

IMPACT OF MNL DISEASE

- The county has 1,716.6 km2 of arable land (over 80% of the country's total land area). The county acreage under food and cash crops is 74,755 and 33,222.5ha, respectively. Using a conservative yield of 4 metric tonnes per hectare, the total loss for the entire 74,755 hectors, if farmers were farming maize entirely, is 299,020 metric tonnes (i.e 74,755 hectors x tonnes)

- With up to 80% of the total population relying on Agriculture as the main economic activity, many families have sunk into poverty due to the failure of Maize farming. This is equivalent to approximately 36.2% of households being considered poor and up to 31% of the population living below the poverty line.
- Agriculture also provides raw materials to agro-based industries in the county and therefore stimulates off-farm employment as well as the use of local resources. Agro-based industries cannot, therefore, thrive in an area facing a catastrophic MLN disease, leading to limited or no employment opportunities in the county.
- Food insecurity in the county is not assured, and many families may in the long run require relief food support from the government
- Residents of Bomet County do not know if the entry of MLN disease on maize could possibly lead to other diseases in both humans and animals

POTENTIAL MEASURES FOR KENYAN SENATE INTERVENTION:

- **Unraveling the Maize Mystery**: Delve into a comprehensive inquiry with the Kenya Plant Health Inspectorate Services and the Kenya Seed Company. Explore why the maize hybrid seeds distributed and cultivated in Bomet County have shown vulnerability to MLN diseases. Demand a detailed account of the intervention strategies employed over the past twelve years. Is this an isolated incident in Bomet County or a deliberate act of economic sabotage? These questions demand answers to uncover the truth behind the maize predicament.
- **Empowering Farmers Through Knowledge**: Investigate why the Ministry of Agriculture Kenya and the local Bomet County Agriculture Department have neglected the crucial task of educating farmers in the region. Inquire why sensitization programs aimed at enlightening farmers about disease prevention and alternative crop options have not been implemented. Suggest the provision of alternative crop varieties, such as Sorghum and Finger Millet, which can thrive under local conditions and offer a robust defense against the prevailing food insecurity challenge.
- **Shielding Farmers from Losses**: Scrutinize the absence of crop insurance initiatives for farmers in susceptible regions. Why has the Ministry of Agriculture not extended this safety net to shield farmers from significant economic losses resulting from crop failures? The Senate must explore the feasibility of establishing crop insurance mechanisms to safeguard the livelihoods of farmers who tirelessly contribute to the nation's food production.
- **Foresight and Food Security**: Raise awareness about the impending threat to national food security due to the rapid spread of this disease, as confirmed by credible scholarly articles and research papers. The Ministry of Agriculture should be reminded of the dire consequences that could unfold if action is not taken promptly. The Cabinet and the National Security Committee need to acknowledge that this issue poses a substantial risk to the country's food supply and, consequently, the overall well-being of its citizens.

By addressing these pressing concerns and urging the relevant authorities to take immediate action, the Kenyan Senate can demonstrate its commitment to safeguarding agricultural sustainability, farmer welfare, and the nation's food security.

Farmers Representatives who contributed to this Petition

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6:2, 125-140, DOI:." *Investigation of Maize Lethal Necrosis (MLN) severity and cropping systems*

mapping in agro-ecological maize systems in Bomet, Kenya utilizing RapidEye and Landsat-8

Imagery, Geology, Ecology, and Landscapes, 6:2, 125-140, DOI:, 2022.

Climate Risk Profile
Bomet County

Highlights

- Bomet County is endowed with vast areas of fertile land and high rainfall. Agriculture is the main economic activity with over 80% of the total population engaging in crop and livestock production. The sector also provides raw materials to agro-based industries in the county and therefore stimulates off-farm employment as well as the use of local resources. Despite the county's favourable climatic conditions, 31% of the population lives below the national poverty line.

  - In spite of good rains and soils, food insecurity is a critical issue in Bomet County with approximately 36.2% of households being considered food-poor. Food scarcity peaks between the months of January and April each year, when harvested stocks are generally depleted.

    - Food insecurity in the county can be partly attributed to the occurrence of climate related hazards. These include: drought, uncertainty in growing seasons (onset and duration), intense rains as well as changes in weather and climate over time. These hazards have been coupled with several agricultural challenges such as prohibitive prices of agricultural inputs, pests and diseases, post-harvest losses amongst others.

      - The most common adaptation strategies to climate hazards for crops include planting of improved varieties, staggered planting, in-field soil and water conservation practices, tree planting, food storage, value-added processing and small scale water harvesting. For livestock, main adaptation strategies include improved livestock breeds, water harvesting, breed diversification, fodder production and feed conservation.

      - Longer term resilience and adaptation strategies suggested for the County include expansion of cold storage facilities for crop and livestock products, expansion of water harvesting and efficient irrigation, investing in local processing facilities for key value chain commodities and capacity building of cooperatives on agricultural marketing.

      - Off-farm services such as early warning systems; agricultural extension trainings on climate hazards and good agricultural practices; and market information are offered to farmers to increase their climate-adaptive capacity. Such services are offered by a variety of actors, from government (such as the KMD, veterinary, agriculture, fisheries and livestock departments) and NGOs. Women and youth are among the most vulnerable groups in the county, with the lowest adoption rates of adaptation strategies.

    - The capacity to develop and deliver relevant and timely climate and weather information to farmers within the county is curtailed by limited coordination between stakeholders, poor communications infrastructure, overstretched human capital, and financial resource constraints. Greater effort could be placed on developing innovative climate information systems and also involving farmers themselves in the interpretation of forecasts and identification of response strategies.

  - Several programs and policies aimed at addressing topics related to climate risk and vulnerability have been put in place and implemented by various actors including government departments, non-governmental organizations, private sector, community-based organizations and cooperatives. However, the programs and policies face challenges of coordination and collective efforts by the various stakeholders.

Kenya Climate Smart Agriculture Project

Republic of Kenya

WORLD BANK GROUP

List of acronyms

ACK	Anglican Church of Kenya
AI	Artificial Insemination
AEZ	Agro-ecological Zone
AFC	Agricultural Finance Corporation
ASDS	Agricultural Sector Development Strategy
ASDSP	Agricultural Sector Development Support Program
ATC	Agricultural Training Centre
CBO	Community-Based Organization
CBPP	Contagious Bovine Pleuropneumonia
CEAP	County Environmental Action Plan
CFA	Community Forest Association
CGA	Cereal Growers Association
CIDP	County Integrated Development Plan
CSA	Climate-Smart Agriculture
DVS	Department of Veterinary Services
EADDP	East Africa Dairy Development Program
EAMDA	East Africa Market Development Associates
EMCA	Environmental Management and Coordination Act
ERA	Economic Review Agriculture
FAO	Food and Agriculture Organization of the United Nations
GoK	Government of Kenya
IDA	International Development Agency
IDP	Internally Displaced People
ITK	Indigenous Traditional Knowledge
KALRO	Kenya Agricultural and Livestock Research Organization
KAVES	Kenya Agricultural Value Chain Enterprises
KCSAP	Kenya Climate-Smart Agriculture Project
KDFF	Kenya Dairy Farmers Federation
KEPHIS	Kenya Plant Health Inspectorate Service
KES	Kenya Shilling
KFA	Kenya Farmers Association
KFS	Kenya Forestry Service
KIHBS	Kenya Integrated Household and Budget Survey
KMD	Kenya Meteorological Department
KMS	Kenya Meteorological Service
KRCS	Kenya Red Cross Society
KWEN	KonyomWenditai Empowerment Network
KWFT	Kenya Women Finance Trust
MNLD	Maize Necrosis Lethal Disease
NCCAP	National Climate Change Action Plan
NCCRS	National Climate Change Response Strategy
NCD	New Castle Disease
NEMA	National Environmental Management Authority
NGO	Non-Governmental Organization
PAFID	Participatory Approaches for Integrated Development
PCN	Potato Cyst Nematode
PSP	Participatory Scenario Planning
RCPs	Representative Concentration Pathways
SACCO	Savings and Credit Cooperative Societies
SDCP	Smallholder Dairy Commercialization Programme
SHoMaP	Small Holder Horticulture Marketing Programme
TIMPs	Technologies, Innovations and Management Practices
UNICEF	United Nations Children's Fund
USAID	The United States Agency for International Development
VC	Value Chain
VCC	Value Chain Commodity
WASH	Water Sanitation and Hygiene
WV	World Vision

Bomet

Foreword

Climate change is becoming one of the most serious challenges to Kenya's achievement of its development goals as described under Vision 2030. Kenya is already highly susceptible to climate-related hazards, and in many areas extreme events and variability of weather are now the norm; rainfall is irregular and unpredictable; while droughts have become more frequent during the long rainy season and severe floods during the short rains. The arid and semi-arid areas are particularly hard hit by these climate hazards, thereby putting the lives and livelihoods of millions of households at risk.

In 2010, Kenya developed a National Climate Change Response Strategy (NCCRS) which recognized the importance of climate change impacts on the country's development. This was followed by the National Climate Change Action Plan (NCCAP) in 2012 which provided a means for implementation of the NCCRS, highlighting a number of agricultural adaptation priorities. The focus of these initiatives has been at the national level, and there is need to mainstream climate change into county level policies, programmes, and development plans; therefore ensuring locally relevant, integrated adaptation responses with active involvement of local stakeholders.

The Government of Kenya (GoK) through the Ministry of Agriculture, Livestock and Fisheries (MALF), with funding by the International Development Agency (IDA-World Bank Group) is therefore implementing the Kenya Climate-Smart Agriculture Project (KCSAP). This projects objective is to increase agricultural productivity and build resilience to climate change risks in targeted smallholder farming and pastoral communities in Kenya, and in the event of an eligible crisis or emergency, to provide immediate and effective response. This Climate Risk Profile has been conducted within the framework of KCSAP and aims to inform county governments and stakeholders on the climate change risks and opportunities for agriculture so they are able to integrate these perspectives into county development.

This document presents the Climate Risk Profile for Bomet County which has a climate change vulnerability index of 0.473, higher than the national index of 0.431[1]. The county is vulnerable despite its disposition as one of the regions with high agricultural potential. In the recent past, Bomet county has suffered from anomalies in weather especially droughts and delayed rain fall which have significantly reduced the productivity of major crops in the area such as tea and maize. For instance, the 2017 prolonged drought in the country affected Bomet County in many ways an example being the forest fire that consumed almost 50 acres of vegetation of Chepalungu forest and killed a number of goats[2]. A similar case was experienced in 2015, where most farmers lost their crop due to a persistent drought[3]; impacts which partly explain the high food insecurity in the county where for instance 36% of the children are stunted[4]. The examples among many more are evidence that the effect of a highly variable climate have and will continue to affect even the characteristically wet counties like Bomet. Despite the current on-going interventions for increasing resilience of the agriculture sector to climate variation and change, devotion of more resources in ensuring institutions have the capacity to deliver the necessary services to increase adaptation of climate smart interventions, and addressing the current policy gaps will go a long way in ensuring secure livelihoods, food security and a healthy environment.

The profile is organised into six sections, each reflecting an essential analytical step in understanding current and potential adaptation options in key local agricultural value chain commodities. The document first offers an overview of the county's main agricultural commodities key for food security and livelihoods as well as major challenges to agricultural sector development in the county. This is followed by identification of the main climatic hazards based on the analysis of historical climate data and climate projections including scientific assessment of climate indicators for dry spells, flooding and heat stress among other key climate hazards for agriculture. The document continues with an analysis of vulnerabilities and risks posed by the hazards on the respective value chains. Based on these vulnerabilities, current and potential on-farm adaptation options and off-farm services are discussed. The text also provides snapshots of the enabling policy, institutional and governance context for adoption of resilience-building strategies. Finally, pathways for strengthening institutional capacity to address climate risks are presented.

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1   Source: GoK; UNDP (2013b).
2   https://citizentv.co.ke/news/50-acres-of-vegetation-goats-burnt-in-bomet-forest-fire-155159/
3   http://www.ipsos.co.ke/NEWBASE_EXPORTS/Brookside/150319_Kass%20Weekly_34_9436b.pdf
4   GoK (2014b).

Agricultural context

Economic relevance of farming

Bomet County is located in the highlands of the South Rift Valley region of south western Kenya in an area commonly referred to as Kenya's high potential cereal and dairy livelihood zone. The county is bordered by Kericho County to the north, Nyamira County to the west, Narok County to the south and Nakuru County to the northeast. The County covers an area of 2037.4 km² and is subdivided into 5 sub-counties namely Chepalungu Sub-County (535.8 km²); Sotik Sub-County (479.2 km²); Konoin Sub-County (445.1 km²); Bomet East Sub-County (311.3 km²); and Bomet Central Sub-County (266 km²). The County borders a long stretch of the Mau Forest Complex which is an indigenous forest, home to different species of animals and plants and one of the most important water towers in the country (GoK, 2014a).

Agriculture is the main economic activity in Bomet County with over 80% of the total population engaging in crop and livestock production or being employed on farms. Agriculture is the main source of livelihood and food security in the county and also provides raw materials to agro-based industries and therefore stimulates multiplier effects in off-farm incomes and employment. Adult females provide the largest share of household labour for both crop and livestock production. Hired labour for livestock production is largely dominated by youth. Paid livestock related work is an important income source for both youth and their families. Male and youth headed households are more engaged in off farm and non-farm activities. Farmers in the county use improved seed for cash crops and local seed varieties for traditional food crops such as sweet potatoes and sorghum (GoK, 2014a).

The average annual household income in Bomet County is estimated at KES 187,920[5] and from this households earn an average of KES 94,223.50 (50.1%) from on-farm activities. Livestock production contributes the largest share of on-farm household income averaging KES 118,398 per year (39% of total on-farm household income)[6]. Crop income represents KES 74,190.90 (24.4% of total on-farm household income), KES 8,000 (2.6% of total on-farm household income) from fishing activities, woodlot income averaging KES 24,800 (8.2 % of total on farm household income) pasture income represents KES 26,038.50 (8.6% of total on farm household income and KES 52,110.70 (17.2% of total on farm household income) from other on farm activities (GoK, 2014a).

People and livelihoods

The total population of Bomet County was estimated at 723,813 in the 2009 Population and Housing Census with 359,531 being male and 364,282 being female. About half (49.7%) of the total population is under 15 years. In 2012, the total population was projected to reach 891,168 by 2017 at an estimated growth rate of 2.7%. About 769,282 people live in the rural areas. The county has a total of 142,361 households[7] with an average household size of 5 members. About 50.3% of the county's population was in the economically active age group[8]. However, a total of 160,583 persons are unemployed. Unemployment in Bomet is prevalent mostly among the youth. The major cause of unemployment in the county is low investment in the manufacturing sector and lack of entrepreneurial skills among the youth (GoK, 2013a).

Apart from agriculture, other key economic activities include small-scale industries such as carpentry and mechanics, the jua kali sector, artisanal mining for precious stones and quarrying for stones and sand. The important ones which are currently under exploitation are: murram, ballast and building stones. Local sand is found in Koiwa location in Konoin Constituency and at Kyogong area of Chepalungu constituency. Building stones are also found at Chepkositonik area of Bomet East Sub-County. The main source of energy in the county is wood fuel with approximately 91% of households using wood fuel[9] for cooking (compared to 64.6% at the national level). Electricity coverage in the county is over 60% with all townships such as Sotik, Bomet, Mogogosiek, Sigor and Longisa having been connected to the national grid. However, actual household connection is much lower at 4% owing to the relatively high cost of connection compared to household incomes. Other sources of energy in the county include kerosene, solar energy and biogas which has seen a recent increase in use. (GoK, 2013a)

Approximately 86% of households have acquired formal ownership for their land and this has enabled many of them to participate actively in gainful economic activities as they can easily access credit for development (GoK, 2013a). The people displaced from the Mau forest in Konoin Sub-County are among the households without formal land ownership. The

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5   This includes income from on-farm, off-farm and non-farm activities. Household incomes are not diversified implying that they derive their household income from one source.
6   Livestock mainly from milk, beef and poultry production contribute between 30% to 45% of the total household income (GoK, 2013).
7   Total number of female headed household is 11,389.
8   Labor force age is between 15 to 64 years both male and female.
9   This high percentage can be attributed to the existence of forests both private and public and thus Community Forest Associations (CFAs) in the county benefit widely from the forestry products such as wood fuel.

incidence of landlessness in the county currently stands at only 2%. This came about as a result of the displacement during the Mau forest conservation exercise. These Internally Displaced People (IDPs) are located at Kusumek and Chebugen camps in Konoin Sub-County. The literacy level in the county is generally high with female literacy standing at 76% and male literacy at 64.7% (GoK, 2013a)

Despite the good rainfall and presence of commercial agriculture activities, 31% of the county's population lives below the national poverty line. The most affected divisions are Sigor, Longisa, Siongiroi where rainfall is low; and Sotik and Kimulot where there is a prevalence of landlessness, consequently affecting nutrition. However, no cases of malnutrition have been recorded in the county. The percentage of children who have adequate weight for age in the county is 60.2%. The 2013 County Integrated Development Plan (CIDP) identified climate change and erratic rainfall as key threats to poverty eradication in the county. The Kenya Integrated Household and Budget Survey report (KIHBS) of 2005 indicates that the county's poor are largely concentrated in the major urban centers, the tea estates, IDP camps and in the lower zones of the county (CBS, 2008).

Agricultural activities

The county has 1,716.6 km² of arable land (over 80% of the county's total land area). The total county acreage under food and cash crops is 74,755 and 33,222.5 ha respectively. The higher altitude areas in the northeast of the county are particularly suitable for tea plantations and dairy farming, while the middle part of the county is suitable for maize, coffee, pyrethrum and tea. In the southern parts of the county, livestock and milk production are the main economic activities. The county's geographical and climatic conditions are perfect for the production of fruit and vegetables. However, most households still primarily focus on maize production, with limited on-farm diversification into horticulture.

In terms of climate, the county has generally high rainfall, ranging from 1000-1400 mm annually. The lower highland part of the county has the highest rainfall. Rainfall decreases in the upper midland zone which lies to the west of the rift valley, and further decreases in the upper midland zone in the southern part of the county. The average monthly temperatures in the county range from 16-24°C. The coldest months are between February and April, while the

hot months is between December and January (GoK, 2014a). Rainfall is distributed unevenly throughout the year with April and May being the wettest months and January and February being the driest. Bomet County is located in the high potential cereal and dairy livelihood zone. Bomet County has both gazette and non-gazette forests with the gazetted forests[10] covering an area of approximately 481.1 km². The forests in the county can further be distinguished between indigenous and plantation forests[11]. The county has two gazetted forests: Chepalungu Forest Reserve (≈ 4,811 ha) and Transmara forest block (≈38,000 ha) of the Mau Forest Complex. In addition, the county borders parts of the Southwest Mau forest block. The forests are also the source of major rivers and forest products mainly timber, honey and herbal medicine.
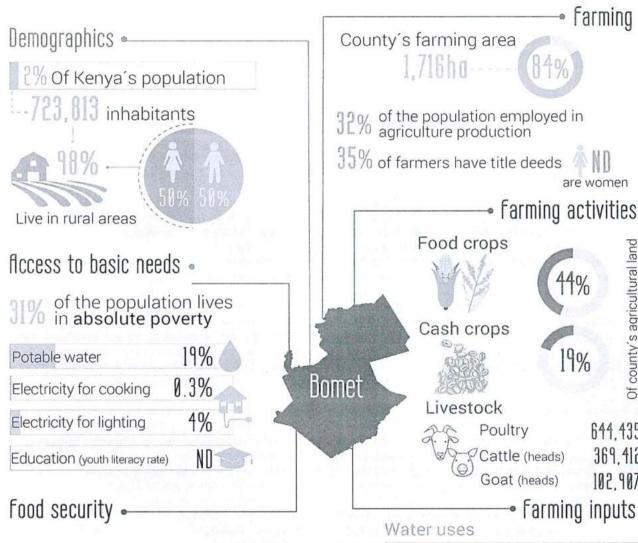
The main farming systems practiced in the county include, small-scale mixed crop-livestock systems and medium to large-scale mono-cropping systems. Agriculture is mainly practiced for subsistence and few commercialized cash crops. The main crops grown for subsistence are: maize, beans, sweet potatoes and cabbages and the major cash crops include tea, coffee and pyrethrum. Horticulture is also practised in the couty. Tea is grown on large plantations that have historically been a key source of employment in the county. Dairy and beef cattle and poultry production constitute the main livestock activities in the county. The main livestock reared include Friesian and Ayrshire dairy cows, various breeds of beef cattle and poultry. Rabbit farming is an emerging enterprise practiced by some farmers in the county. Fisheries and aquaculture are also practiced but at small scale. The main types of fish farmed include tilapia, clarias, Barbus Labeo and various trout species. The county produces over 50,000 kg of tilapia annually. The major rivers that can support fisheries include: Mara, Itare, Kipsonoi, Kiptiget, Nyongores and Amalo; hence, there is potential for aquaculture development in the county. The average smallholder farm size is estimated at 1.5 ha per household and 15 ha for large holders. Most of this land is dedicated to crop and livestock production with a small portion of the land being utilized for the construction of homesteads (GoK, 2013a).

The use of yield enhancing inputs such as organic manure, basal fertilizer and top dressing fertilizer are limited to 11, 61.1 and 6% of the county's farmers respectively. The use of field pesticides, storage pesticides and herbicides is 14.5, 3.7 and 39.1% respectively with only 0.8% of the county's farmers using irrigation facilities. The major constraints related to the

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10   These forests include Tinet in Konoin Sub-County and Chepalungu in Chepalungu Sub-County
11   Chepalungu and Transmara Forest block of the Mau Forest Complex were both originally indigenous but with the human exploitation, there has been reforestation efforts.

Livelihoods and agriculture in Bomet

Demographics

2% Of Kenya's population

723,813 inhabitants

98% Live in rural areas

50% 50%

Farming

County's farming area
1,716ha **84%**

32% of the population employed in agriculture production

35% of farmers have title deeds **ND** are women

Farming activities

Of county's agricultural land

Food crops **44%**

Cash crops **19%**

Livestock

Poultry		644,435
Cattle (heads)		369,412
Goat (heads)		102,907

Access to basic needs

31% of the population lives in **absolute poverty**

Potable water	**19%**
Electricity for cooking	**0.3%**
Electricity for lighting	**4%**
Education (youth literacy rate)	**ND**

Food security

36% of the population suffers from **food poverty**

ND of household **income spent on food**

ND People **undernourished**

36% Children **stunted**

ND Children **wasted**

ND: No data

Infographic based on data from the County Integrated Development Plan (GoK, 2013), the Agricultural Sector Development Support Program (GoK, 2014), and Kenya National Bureau of Statistics (KNBS, 2015)

Farming inputs

Water uses

ND **ND** **ND**

Fertilizer types (% of households)

	13%	Organic manure
NPH	**67%**	Planting fertiliser
	9%	Top dress fertiliser

Pesticide types (% of households)

	20%	Field pesticides
	4%	Storage Pesticides
	43%	Herbicide

Bomet

use of agricultural inputs include limited availability and affordability and perceived ineffectiveness of some inputs – possibly due to inappropriate use. The use of inputs in livestock production is high with 84% of households in the county using dewormers, 81% using acaricides, 77% using mineral supplements and 64% vaccinating their animals. Male-headed households report higher use of agricultural inputs than female-headed households (GoK, 2014a). This can be attributed to the domination of male-headed households in livestock production that includes cattle, goat and sheep and the prohibitive costs associated with agricultural inputs.

Use of farm machinery is low with only 41% of farmers using tractors and 28% using ploughs. Other machinery and equipment used in the county are harrows, pumps and planters. The use of livestock drawn equipment is also common. The majority of farmers use simple tools such as the hoe, jembe and spade. The County Government of Bomet provides machinery to farmers at a subsidized rate; this includes 10 tractors[12] normally used for harrowing, ploughing and mowing (key in harvesting hay[13]). Approximately 80% of farmers rely on improved raised on-farm granaries of various capacities. In addition, the National Cereals and Produce Board (NCPB) have three silos in the county located at Bomet, Ndanai and Sotik towns. The Bomet depot has a capacity of 180,000 bags while the others have a capacity of 100,000 bags each (GoK, 2014a).

Agricultural value chain commodities

A broad diversity of agricultural commodities is grown in the county. Of these commodities, various value chains have been prioritized as being strategic for the county as indicated in the County Integrated Development Plan (CIDP) and the Agriculture Sector Development Support Programme (ASDSP) as well as by government institutions such as the Kenya Agricultural and Livestock Research Organization (KALRO). For the development of this County Climate Risk Profile, four major value chain commodities (VCC) were selected for in-depth analysis based on: prioritization in County Frameworks and Programmes; economic value (KES/bag or KES/livestock or KES/unit livestock product)[14]; resilience to current weather variability and future climate change; and number of economically active people engaged in the commodity's value chain (including vulnerable groups, women, youth and the poor). The selected VCCs were banana, Irish potatoes, sweet potatoes and local chickens.

Banana

The banana value chain has been gaining importance for food security and livelihoods of farmers in Bomet County. It is estimated that 61% of the total population are engaged across this value chain and this is due to the fact that the crop is resilient to dry spells, pests and diseases. In terms of geographical coverage, banana production is well spread across all five sub-counties. It is also a commodity that is grown by all groups of farmers and it is particularly favoured by women and youth. This value chain is characterized by small-scale, mixed, subsistence farming systems in the areas of Sotik Sub-County, Bomet Central Sub-County including the areas of Silbwet, Tenwek, Cheptalal, Ndaraweta, Konion Sub-County including Kimulot, Chebangang and Kapkoros. Large-scale, commercial mono-cropping farming systems are only found on Nogirwet.

Seedlings and advisory services for banana production are provided by the county's agricultural extension staff as well as by KALRO and other partners. Due to the popularity of banana production, farmers now also source suckers from neighbours and there are a number of banana tissue culture nurseries across the county. Bomet East Sub-County in Kembu is the main center for acquisition of good quality planting material that is free of diseases. Most of the farmers apply fertilizers to increase their yield and for proper establishment of the banana crop. Fertilizers are sourced from farm input suppliers in the towns and at farm level. Farmers also use organic manure. Youth-headed households use more planting fertilizer and top dressing fertilizer compared to male- and female-headed households, on average 50 and 50 kg respectively. This can be attributed to the readily access[15] and availability of information with regards to fertilizers by the youths. Male-headed and youth-headed households approximately use similar amounts of organic manure 106 kg and 103 kg respectively. This can be attributed to the ownership of livestock by the men. Farm labour for small-scale production of bananas is sourced at household level and hired in the event of large-scale farming. (GoK, 2013a). Once harvested the bananas are transported to main collection, marketing and storage centers in Bomet town, Sotik, Mogogosiek, Mulot, Chebole, Kapkwen where they are either sold in local markets or transported for sales outside the county (Nairobi, Mombasa and Nakuru).

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12 2 tractors for each of the 5 sub-counties in the county.
13 Important in stall fed production systems.
14 As stated in the 2015 Economic Review of Agriculture (ERA).
15 Income from non-agricultural income generating income such as boda boda, mining, jua kali among others

Irish Potatoes

Between 41-60% of the county's population are engaged along the Irish potatoes value chain. Irish potatoes have been promoted as a strategic crop for value chain development in the county largely due to its fast growth, high productivity and high profit making potential. In Bomet County, this value chain is characterized by large-scale commercial farming systems in Bomet Central including areas of Kipsonoi, Kiplelji, Silibwet, Tenwek. In the areas of Sotik and Konoin Sub-Counties and Gelegele, it is characterized by small-scale, mixed cropping (tomato and livestock such as dairy) systems. Irish potatoes take four months to mature and with irrigation and timely access of seeds, farmers can harvest up to 3 times a year. Conservation agriculture and crop rotations are commonly practiced as a means of managing pests.

Between 2012 and 2013 the area under Irish potato production in Bomet County increased from 2,847 to 3,924 ha, an increase of over 37%. The total quantity produced increased from 43,600 tons to 74,504 tons during the same period representing an increase of 70% (GoK, 2015). These figures underline the growing importance of Irish potato in the county. The selection of clean, pest and disease free planting material is key in the production of potatoes and supported by institutions such as KALRO, KEPHIS, Kisima farm in Meru, and extension officers. Land preparation, production and harvesting are done by households and hired labour utilizing both simple farm tools and machinery such as tractors.

Potato is one of the commodities for which agricultural credit is available, either in the form of loans or else in the form of inputs for production. The Dutch Robin potato variety is the preferred variety in the county as it is suitable for products such as potato crisps. Bomet County is the leading provider of potatoes used by Deepa Industries[16] which is one of the largest manufacturers of potato snacks[17] in Kenya.

The Irish Potato Value Chain (VC) is affected by a number of pest and diseases such as bacterial wilt and Potato Cyst Nematode (PCN) and thus the use of pesticides is common. Potato aggregation centers (cold stores) are found at Tegat and Mogoma both in Bomet East. Key actors involved in linking potato farmers to buyers include, Kenya Midland Sacco, Deepa Industries, NORDA and the Agribusiness Marketing office at the county headquarters. Challenges to potato production include low availability of certified seeds, pests and diseases such as bacterial wilt and PCN, and lack of structured markets.

Sweet Potatoes

Sweet potato is a heat loving, drought tolerant food crop that has widely been accepted in Bomet County. It is mainly grown in the lowlands of the county: Chepalungu, Bomet East, Sotik and parts of Bomet Central Sub-Counties. It is also used as a cover crop and thus key in conservation agriculture. Some farmers plant the sweet potatoes vines under the maize as a cover crop. Sweet Potatoes are characterized by subsistence, small-scale, and mixed farming systems across the county. Between 2012 and 2014a the area under sweet potato production in Bomet County increased from 429 ha to 2,333 ha. The total quantity produced increased from 4,650 tons to 30,971 tons during the same period (GoK, 2015). This indicates that the sweet potato VC has high potential. Most farmers are now shifting to this VCC because it is a drought tolerant crop with the potential to enhance food and nutrition security.

The county government through the Sweet potato project[18] has supported farmers with high quality vines while organizations such as KALRO have been conducting training on sweet potato production. Demonstration farms and field days are used as a vital avenue in disseminating information and knowledge on this VC. Most farmers involved in this value chain use organic manure for their crops rather than mineral fertilizers. This is largely due to financial constraints. Sweet potatoes are sold unprocessed, however the Bomet County Cooperative Union set up a sweet potato bakery to bake cakes and bread. NGOs such as World Vision are involved in some aspects of the sweet potato value chain through the provision of processing and packaging equipment for making potato crisps in Chepalungu Sub-County, in Chebonyo, Cheleget, Saboson, Kamaget, Lelaitich and Mogor.

Chicken (local)

It is estimated that over 81% of the total population in Bomet County are engaged across the local chicken value chain either for meat, eggs, and supply of feeds, vaccine and income. The value chain is characterized by small-scale, subsistence, mixed farming systems. Local chicken breeds are relatively easy to manage. They are often left to roam freely and scavenge for food with very little supplementary feeding and minimal additional inputs. In some cases, farmers

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16 Popularly known as Tropical Heat.
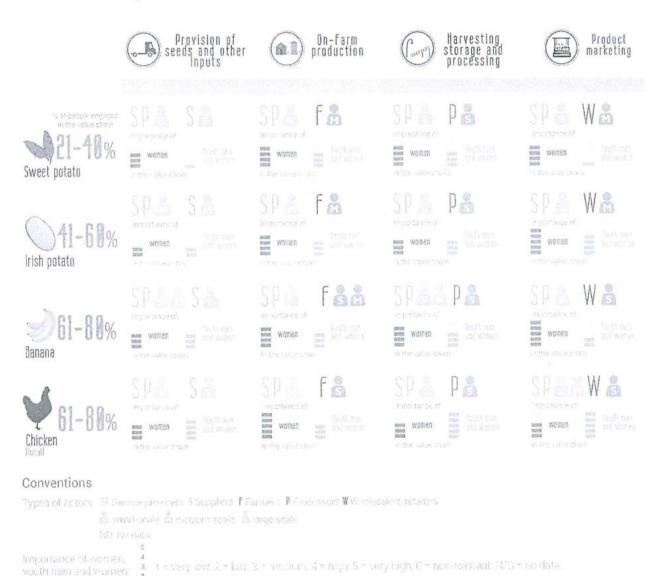17 Potato crisps, chevda and potato sticks.
18 This project started in April 2016

use stall feeding and improved housing to maximize productivity especially when commercial production is the main aim. Because of the largely informal nature of chicken production in the county, information related to inputs used and production volumes is limited.

Chicken diseases, such as Newcastle disease (NCD) and fowl pox are a great challenge to production and vaccination as well as cleanliness and decontamination are important aspects of production. Vaccination is offered by the Department of Veterinary Services (DVS) as well as by private providers. Local breeders and the agro-dealers are involved in the supply of chicks across the county. This value chain is key in both egg and meat production in the county.

Agricultural value chain commodities in Bomet

Infographic showing four value chain stages: Provision of seeds and other inputs, On-farm production, Harvesting storage and processing, Product marketing — for four commodities: Sweet potato (21–40%), Irish potato (41–60%), Banana (61–80%), Chicken (local) (61–80%).

Conventions

Types of actors: SP Service providers; S Suppliers; F Farmers; P Processors; W Wholesalers/retailers

small-scale; medium scale; large-scale

ND No data

Importance of women, youth men and women: 1 = very low; 2 = low; 3 = medium; 4 = high; 5 = very high; 0 = non-existant; N/D = no data.

Agricultural sector challenges

Despite the County's fertile soils, adequate rainfall, diverse range of commodities grown, and high productivity, there are still a number of challenges in the agricultural sector. These challenges relate largely to poor crop husbandry, use of uncertified seeds, lack of planting materials, pests and diseases, and low application of fertilizer and other farm inputs due to prohibitive prices. The county has a conducive agricultural environment and there is an overreliance on rain fed agriculture which has become unreliable in recent years. The use of climate resilient, productivity enhancing technologies such as irrigation and greenhouses is limited among smallholder farmers in the county. However, gains from the use of these enhancing technologies are hampered by poor crop and livestock husbandry techniques, use of uncertified seeds, and limited application of fertilizer and other farm inputs. Underdeveloped input market infrastructure makes quality inputs such as seeds, sometimes unavailable. For example, the lack of planting materials has sometimes affected productivity of pyrethrum[19] and coffee, the two main cash crops in the lower areas of Bomet County.

There is a wide range of pests and diseases affecting crop and livestock production in the county. Cattle diseases include, foot and mouth disease, Rabies, Contagious Bovine Pleuropneumonia (CBPP), anthrax and black quarter; and in local chicken viral diseases such as NCD and fowl pox are experienced across the county. Many of these diseases are affected by weather and climatic conditions, with some being more prevalent during wet periods and others during periods of drought. In crop production there are also a wide range of pests and diseases that are affecting different value chains across the county; they include MNLD, fall army worm[20] in maize, PCN, bacterial wilt, potato blight in potatoes among others. The main water sources in the county (Nyongores, Kipsonoi, Itare, Kiptiget, Chemosit, Amalo, Mara and Sisei Rivers) have been polluted through poor use and disposal of farm chemicals. Erosion has also increased due to stream bank cultivation; this reduces water flow as well as water quality which affects crop and livestock production negatively.

The livestock sub-sector also faces low productivity due to poor cattle breeds, lack of quality feed and pastures and low adoption of appropriate technologies such as feed conservation, vaccination. Value addition of animal products is limited with most sales consisting of unprocessed milk, raw goat meat and chicken meat. Limited functionality of input and output market chains expose smallholder farmers to exploitation by middlemen. In addition, the underdeveloped markets for farm produce within the county often result in high post-harvest losses and low prices for agricultural produce.

About 80% of farmers rely on on-farm grain storage, however, inadequate post-harvest technologies contribute to high post-harvest losses (infection by pests and fungi). While farmers' cooperatives do exist to support collective marketing and bargaining, their structures are often weak and subject to low participation and high failure or dormancy rates. Despite the wide range of financial institutions smallholder farmers in the county have limited access to credit and agricultural insurance mostly due to lack of collateral and the high risk associated with smallholder agriculture. When credit and insurance are available they are often at high interest rates and premiums which are not attractive for smallholder farmers. The extension service is often overstretched due to the high farmer - extension worker ratio. This is further exacerbated by the limited knowledge of extension agents on emerging issues such as climate change.

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19 Kenya is the leading exporter of Pyrethrum in the world and Bomet is one of 19 counties in the country that produce it.
20 This is an emerging pest affecting maize across the county.

Climate change-related risks and vulnerabilities

Climate change and variability: historic and future trends

Bomet County has a generally cool climate with mean annual temperatures being below 20 °C throughout most of the county. The county has moderate mean annual rainfall of between 1000 and 1250 mm per year over most of the county. The lower highland part of the county has the highest rainfall, with rainfall decreasing in the upper midland zone which lies to the west of the rift valley, while the upper midland zone in the southern part of the county has the lowest annual rainfall. Although the County is not particularly dry or vulnerable to droughts, Bomet was among several non ASAL counties identified as being affected by the 2016/17 drought in Kenya. Incidences of extreme rainfall resulting in flash floods have also been recorded and farmers have testified to uncertainties in the start of the growing season.

Analysis of temperature trends in the county over 25 years (1981 to 2005), showed that temperatures have increased by approximately 0.5 °C for both the first and second seasons. Despite these increase in temperatures in both seasons there has not been an increase in the number of heat stress days[21]. On the other hand, analysis of average annual rainfall, measured over a 35-year period (1981-2015), showed no significant change in both seasons. Rainfall has however become more variable, with an increase in extremes (both highs and lows) from year to year, which has resulted in an increase in both flood and drought risk in the first season and an increase in drought risk in the second season.

Looking ahead to the period 2021-2065, climate projections based on two representative concentration pathways (RCPs[22]) indicate that under both scenarios mean temperatures are expected to continue to increase. This results in an increase in drought risk, with the number of consecutive drought stress days[23] rising from an historical average of less than 60 days in each half of the year to as high as 80 consecutive dry days. Under both scenarios there is also expected to be an increase in flood risk with the maximum 5-day precipitation average rising by approximately 20-25% from the historical average. Under the high emissions scenario there is also expected to be a reduction in rainfall in both seasons.

These changes in temperature and rainfall also have an effect on season onset and duration however the effects are different depending on the level of GHG emissions. Under the low emissions scenario, both the first and second seasons are expected to start lateral though the length of the second season is also expected to increase slightly. On the other hand, under the high emissions scenario season onset is similarly expected to recede however in this case the length of the second growing season is expected to reduce. Moisture stress[24] is also expected to increase under both scenarios although the magnitude is more pronounced under the high emissions scenario. Although the projections of future climate change under the two GHG emissions scenarios show some differences, both indicate the likelihood of noteworthy changes in the weather and climate of the county with probable impacts on crop and livestock production.

Climate Perceptions by the farmers

According to farmers, there has been an ongoing and intensifying change in climate and weather patterns in Bomet County in recent years. These changes have included: increased unpredictability in rainfall patterns in terms of amount and distribution as well as a rise in temperatures. Because of the uncertainties associated with the beginning and end of the growing season (a while back, the long rains would start mid-March but nowadays they start as late as in May) farmers are unable to prepare well for planting and harvesting. This has resulted in extensive crop losses and food insecurity.

Farmers believe that human activities such as environmental degradation and deforestation (caused by clearing of land for agriculture and grazing as well as the need for wood for construction and energy) and the increased demand of fuelwood for production of tea by the KTDA have led to erratic rainfall, increased river siltation, reduced water availability and that these in turn have affected agricultural production and productivity. Farmers noted that there are now long dry spells in the lowlands of Chepalungu and Bomet East and that these are attributed to the deforestation

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21 Indicated by the number of days with a maximum temperature above 35°C.
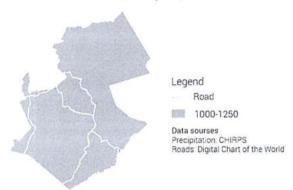
22 The two RCPs, RCP2.6 and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6 and +8.5 W/m2, respectively). The pathways are used for climate modelling and research. They describe two possible climate futures, considered possible depending on how much greenhouse gases are emitted in the years to come. RCP 2.6 assumes that global annual GHG emissions (measured in CO2-equivalents) peak between 2010 and 2020, with emissions declining substantially thereafter. In RCP 8.5, emissions continue to rise throughout the 21st century.

23 Days with precipitation less than 1mm per day.

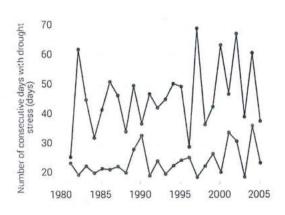24 Number of days with ratio of actual to potential evapotranspiration ratio below 0.5.

Past and future impacts of climate hazards in Bomet

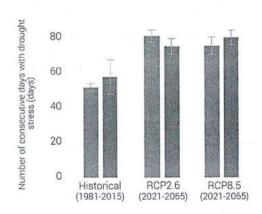## Historical annual mean precipitation (mm/year)

Legend
— Road
▢ 1000-1250

Data sources
Precipitation: CHIRPS
Roads: Digital Chart of the World

Historical annual mean temperature (°C)

Legend
— Road
▢ < 21

Data sources
Precipitation: WordClim
Roads: Digital Chart of the World

Moisture stress hazards

Historical extreme moisture stress events
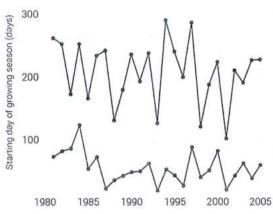

Historical and expected extreme moisture stress events
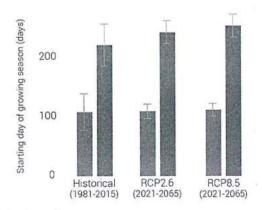
Uncertainity in the start of growing season hazards

Historical uncertainity in the start of growing season stress events

Historical and expected uncertainity in the start of growing season stress events

■ January - June ■ July - December

in Chepalungu forest. In addition, farmers identified the wetland encroachment and streambank cultivation in the highlands of Konoin as some of the reasons for diminishing water availability from the water sources. This phenomenon has mostly affected the lowlands of the county: Chepalungu and Bomet East. Farmers believe that the water abstractions projects[25] at Rivers Nyangores, Kipsonoi and Itare are responsible for some climate related hazards in the county.

Farmers have also noted an increase in the occurrence and severity of wildfires between November 2016 and February 2017, a phenomenon they attribute to increased temperatures. Farmers stated that in the lower parts of the county (Chepalungu and Bomet East), distances to the main water sources (dams and pans) for domestic and livestock purposes have increased particularly during the dry seasons when farmers can trek as far as 5 km. Scarcity of water has also been attributed as a cause for increased cases of human diseases such as cholera. Farmers also reported increased incidence of mosquitoes and malaria due to temperature rises in the county that previously known as relatively mosquito free.

Climate vulnerabilities across agriculture value chain commodities

As indicated by farmers, there are numerous climate related hazards in Bomet County and these hazards have been compounded by various changes in weather and climate over past decades. The impacts of these changes are however not uniform across all agricultural value chain commodities. Climate vulnerability involves socio-economic factors that influence people's ability to cope.

Banana

Moisture stress affects the acquisition of farm inputs and land preparation. Farmers' delay the acquisition of inputs due to the high costs attributed to them and because they spend more time preparing the land due to the extra labour required breaking hardpans. These effects are not felt evenly; some farmers can access improved planting material while the majority depend on traditional suckers. The economically endowed farmers use modern farm machinery to break hardpans compared to poor farmers who lack such infrastructure due to financial constraints.

Moisture stress leads to delayed planting and reduced yields. Women and youth are more affected, as they are more involved in this value chain. Farmers with adequate knowledge on good agricultural practices are less susceptible than those with limited knowledge. For instance, overcrowded stools suffer more moisture stress. Farmers with knowledge on the proper spacing and stool management suffer less. Those adopting minimum tillage, use of tissue culture planting materials are less vulnerable to the negative effects of moisture stress. The economically endowed farmers have the capacity to purchase clean planting material, inorganic fertilizers and prepare land properly[26] with the required machinery such as sub-soilers. Farmers that have limited access to early warning systems by the Kenya Meteorological Services are also more vulnerable than those that receive early warning information.

Moisture stress leads to reduction in bulking quantity and over-ripening, less production and high instances of post-harvest losses. With the reduction in production, transport becomes expensive, as farmers are no longer in a position to offset the overhead costs incurred. Poor infrastructural facilities especially in Konoin Sub-County[27] lead to more vulnerability compared to other areas. Most parts are hilly and the roads are not well maintained hence increasing transportation costs. The lack of on- and off-farm storing facilities also leads to post-harvest losses. For example, farmers in Bomet East are forced to sell their produce locally hence fetching low prices.

Moisture stress affects the prices of the banana due to poor quality and quantity of the produce. The demands of the market are not met due to low supply. This inconsistent supply will consequently lead to future market losses. Farmers with limited knowledge on market information and dynamics will be affected more.

Another climatic hazard that affects the banana value chain is the uncertainty of seasons (onset and duration) with consequences that are more or less similar to moisture stress. Additionally, Uncertainty of seasons (onset and duration) leads to fluctuation and poor prices due to missed market opportunities and unreliable markets. Farmers engaged in contract farming have to deal with the loss of trust due to dishonoured contracts. Some of the factors that make people more vulnerable than others include inter alia: financial constraints where women, youth and poor farmers have limited financial capability to use modern technology to engage in modern farming that do not rely on rainfall such as green houses. These categories

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25 These projects include Sigor water Project and Chepalungu that is almost complete and almost to start respectively
26 Digging of the holes with right dimension.
27 Due to the topography (sloppy)

of farmers do not have enough storage and cooling houses to keep their produce as they await better market prices.

Irish potatoes

Drought/moisture stress is a serious climatic hazard that affects the production of Irish potato as it leads to the creation of hardpan during land preparation and inadequate availability of seeds. Drought/moisture stress affects some parts of the commercial, large-scale farming systems (Kiplelji, Kembu,) and parts of the small-scale, subsistence, mixed farming systems (Gelegele). Drought leads to soil compaction which makes tilling the land more difficult. This consequently leads to high cost of land preparation due to the use of machinery such as subsoilers. Low income from the farmers reduces the chances of acquiring credit facilities. The level of poverty hinders the availability of proper farm inputs

This stress also leads to the emergence of pests and diseases such as whiteflies affecting the leaf surface area. The farmers in the lowlands, the hot and dry agro-ecological zones (AEZ) in Bomet East and parts of Bomet Central suffer most due to the low humidity conditions in the area, thus increasing the prevalence of the whiteflies. Other pests include, spider mites and aphids. Economically empowered individuals have the capacity to source for irrigational infrastructure and thus become less vulnerable compared to the poor. Farmers with limited knowledge on post-harvest handling and management are more vulnerable. Areas with poor road networks such as Merigi/Chemanar are more affected since access to markets becomes a challenge. Drought also leads to the interference by the middlemen (brokers) hence prolonging the value chain and less returns to the farmers. Promotion becomes expensive as the produce is less and thus increases overhead costs. The low quality and quantity of the yields lead to less bargaining power thus fetching low prices. Farmers that have limited knowledge on market information are more vulnerable to exploitation by the middlemen.

Another climatic hazard that affects this VC is intense rain which often leads to high infestation of pest and diseases such as bacterial wilt, potato blight. These pests are expensive to control, and the high incidence of diseases also leads to inadequate supply of clean seeds, thus increased input prices and higher transportation costs as the road network is hampered in the event of intense rain. In the on-farm production, land preparation cost increases. Increased incidences of pests and diseases (late/early blight) require extensive pest management thus leading to increased

production costs. The farms in sloping areas such as Ndarawetta, Merigi are more affected due to the high rate of leaching leading to poor yields. The economically endowed farmers engage in good agronomic practices as they have the capacity to absorb the climatic shocks through the implementation of proper infrastructure. Soil fertility also varies across the county. The lowlands of Bomet East and Sotik are characterized by clay soils that get logged thus affecting the productivity of this value chain. Intense rain impacts the large-scale commercial farming systems in Kapkoros, Ndaraweta, Silibwet, Tenwek and parts of the small-scale, mixed, subsistence farming systems in Cheptalal, Koiwa, Mogogosiek, Sotik areas.

Pests and disease control varies according to the level of credit facilities. Poor farmers often do not have access to credit facilities due to the lack of collateral that is a prerequisite by most financial institutions. Farmers with adequate knowledge and skills in the management of the crops are less vulnerable than the farmers with limited access or no access to knowledge and skills. The increased labor costs are likely to be felt more by the poor farmers as compared to the economically endowed farmers. Intense rain leads to high cost of transport. Areas with poor road networks such as Merigi and Chemanar are more affected than areas that have well-developed road infrastructure. Poor storage facilities lead to high perishability.

Sweet potatoes

Moisture stress/drought affects the sweet potato value chain, in particular the small-scale mixed, subsistence farming systems in Chepalungu Sub-County, which includes areas of Chebunyo, Kaboson, and Sigor. Moisture stress reduces the availability of planting material at the bulking sites, thus the extension advice is thus less likely to be adopted. Poor farmers are not in a position to pay for planting material that retails at higher prices during periods of drought and thus are more vulnerable than the economically endowed farmers that can afford the high prices prevailing in the market. Poor farmers also typically keep less animals and thus have limited farmyard manure during periods of drought/moisture stress. Farmers adopting new varieties are less vulnerable than farmers opting for traditional varieties. The extension officer to farmer ratio is low and thus the dissemination of the extension service is curtailed thus making the farmers more vulnerable as they have limited knowledge transfer

Land preparation, especially in the lowland areas which predominantly covered with clay soils, becomes more difficult due to hardpans. This mostly affects

farmers that use simple hand tools compared to those using machinery such as sub-soilers. Because of this, farmers often have to delay planting which results in low production and low quality tubers that break during harvesting. Moisture stress/drought leads to increased costs of post-harvest activities because the overhead costs will be similar but the produce will be less. Poor quality produce fetches low prices and increases the cost of processing. Farmers in the lowland areas such as Kaboson in Chepalunguare are likely to be more affected because these areas are prone to dry spells. Uncertainty of seasons (Onset and duration) also affects the sweet potato value chain adversely in the county, in particular, the small-scale, subsistence farming systems in Bomet East, Sotik and parts of Bomet Central. Uncertainty of season (onset and duration) leads to delays in input supply, untimely sourcing of planting material and organic manure, low uptake of technology and ill-timed dissemination of information. Most farmers do not have access to early warning systems and weather advisories. The low farmer - extension officer ratio leads to low uptake of technologies.

This climatic hazard also leads to improper land preparation, poor yields and production. The reliance on the rain fed agriculture makes farmers more vulnerable to these consequences. Farmers who do not have the machinery such as tractors and oxen ploughs are worse off compared to their counterparts as this machinery helps in quick farm preparation. It also has an adverse impact on the post-harvest where the cost of collection and handling increases due to the low volumes. There are also varied maturing periods due to the different planting times. The output market is also affected negatively the low volumes leads to high promotion cost, poor linkages to the market and low prices. The lack of adequate storage facilities, low extension staff to farmer ratio and the poor road network makes farmers more vulnerable.

Chicken (local)

Local poultry are adversely affected by drought, especially in the hot and dry agro ecological zones of Chepalungu Sub-County (Chebunyo, Kaboson, Sigor) that practice small scale, subsistence, mixed farming systems as they are vulnerable to inadequate feed and water, and to increased incidence of diseases such as Newcastle disease. Drought also leads to high prevalence of external parasites such as flies and mites. This leads to a decline in production and/or to stock loss. The effects of drought are not experienced equally by all farmers; wealthier farmers have the capacity to procure water or engage in water-harvesting techniques and purchase and/or store supplementary feed. Conversely, the increased costs of production adversely impact the poor and result in low volumes of trade with increased prices. Low extension staff: farmer ratio in the county, increases the vulnerability of the farmers that need the knowledge in their production systems to increase their availability. The economically endowed farmers are likely to source private service providers to get the knowledge.

In post-harvest stage, grading of the eggs is affected as the shelf life of the eggs is reduced and thus the quality of the eggs, this consequently affects the household incomes. Poor handling and storage facilities in the county is linked to the financial capability of the farmers, the pro poor are unable to purchase the comprehensive storage infrastructure and thus suffer from post-harvest losses.

With regards to the output market, farmers that have adequate market information are less susceptible to the climatic consequences as compared to farmers that do not receive the market information[28].

Floods affect road networks, threatening inputs availability and prices. Moreover, water damage to housing and to storage facilities compromise poultry health and survival, as there is increased incidence of diseases such as fowl typhoid. This is pronounced in the small scale, subsistence, mixed farming systems in the Konoin, Bomet Central and parts of Sotik Sub-Counties. The low extension/veterinary services officer: farmer ratio increases the vulnerability of the farmers as the officers are over stretched with regards to addressing the high incidences of the diseases in this climatic hazard. Need for deworming, as there is increased prevalence of the endo parasites, increases and this affects the poor farmers as the necessary drugs are expensive and prices increase due to the increased demand, leading to high morbidity of the stock. Marketing activities are also affected. Reduced supply and increased demand lead to high prices for local poultry. There is delayed delivery of the local chicken and its products to the market due to the impairment of the road infrastructure during this climatic event. The poor road network affects the transportation and the marketing of this value chain. The vendors also lack the organization skills to put up proper storage facilities which can help VC players market their products when prices are favourable and therefore derive value from this value chain

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28 From the marketing department in the agribusiness, the media

Adaptation to climate change and variability

On-farm adaptation practices

Current adaptation options in Bomet County are aimed at increasing farmers´ capacity to cope with risks and adapt to climate change and variability. These interventions have been conceptually mapped to specific vulnerabilities in the 4 major VCCs as discussed below.

The department of water is encouraging water harvesting strategies particularly public institutions where they provide water tanks to schools, health facilities and have issued 250 water tanks to public institutions. The department collaborates with other institutions to ensure water security such as Water Service Trust Fund, UNICEF, World vision, Kenya Red Cross (KRC). To avoid contamination of water, there is improvement and protection of water sources such as the springs, through the spring box or the stand tap. There are surface water reservoirs such as dams and water pans for livestock production across the county. Dams are found in the drier zones of Chepalungu, parts of Sotik sub-county and Longisa in Bomet East sub-county. Households with corrugated iron roofs, public and private institutions engage in roof water harvesting and use the stock during the dry spell when they have water shortage. Adoption of the irrigation facilities across the county majorly in the lowlands is being promoted through the Bomet Integrated Development Programme in Chepalungu, the Bomet East-Chebaraa Irrigation scheme and Nogirwet irrigation scheme that is collaboration between the county Government of Bomet and the KRC.

Agroforestry is widely practiced in Bomet County due to reduced land sizes and the awareness of benefits that accrue from the practice. The demand for wood fuel by tea factories in the county has resulted in most farmers combining both trees and crops in their farming activities. The gains made from agro-forestry are immense as the decomposition of tree litter and pruning can substantially contribute to maintenance of soil fertility. Agro-forestry also controls runoff and soil erosion, thereby reducing losses of water, soil material, organic matter and nutrients. Growing of fruit trees is also being encouraged by various agricultural stakeholders so as to enhance the tree cover to the desired national standard of 10 % by the year 2030. Industrial fertilizer is expensive and out of reach for most farmers and as such use of nitrogen fixing tree species such as *Leucaena leucocephala*, *Sesbania sesban* and *kajianas kajian* are an alternative to improvement of soil fertility.

Fodder trees have the potential for alleviating some of the feed shortages and nutritional deficiencies experienced in the dry season. Farmers also use molasses, Napier grass, and Boma Rhodes. Farmers have diversified the fodder crops; not only do they rely on the grasses but use legumes as well. The county government own 10 tractors where 5 are fitted with mowers and the other 5 fitted with balers[29] used for pasture conservation. The county government through the livestock department also issue pasture seeds to farmers and train them on diversification and feed formulation options. AI services are provided by DVS and private service providers. The former provides subsidized AI services attracting a high demand by farmers. Vaccination is also under the jurisdiction of the DVS and is subsidized with the exception of the rabies vaccination. In the fisheries department, the fish farmers destock the fish ponds[30] in the event of climate extremities such as dry spell while others engage in feed formulation, Sisich Fish Farmers cooperative society are actively involved in feed formulation.

Value addition in agriculture is any activity a farmer performs outside of traditional agricultural production to receive a higher return per unit of any product sold. This includes activities such as agri-tourism, storage, processing and marketing (Ntale *et al.*, 2014). A high number of households (73%) add value to cereals, vegetables (27%) and trees (24%) compared to the other crop categories. Grading/packing is the main value addition activity across all the crop categories (GoK, 2014a). Some of the value added products include sweet potato bread, cakes, crisps and Irish potato crisps. Different types of value addition are undertaken within each livestock product category. Much of the value addition is done by male adults. This can be attributed to the ownership of the livestock and thus key decision makers in the livestock. A high number of households add value to milk through fermentation, to the popular *mursik*, yoghurt, cooling, boiling, grading, pasteurization and packaging. Value addition for eggs include grading, packaging, boiling and for chicken de-feathering, boiling, salting and packaging. Diversified of farm enterprises include bee keeping, and switching from rain fed food crops to irrigated horticultural production to cushion against climatic shocks and increase household income.

The main sources of climate related information in the county are meteorological department and Indigenous

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29 Data from the department of agribusiness.
30 The fish farmers use pond liners.

Traditional Knowledge (ITK) while the channels of dissemination are radio[31], agricultural officers and television. Other dissemination channels include but are not limited to: public extension, community based organizations (CBOs) and partners. More female-headed households had higher access of climate information from ITK and radio, while the majority of youth-headed and male-headed households obtained climate related information from television.

Annex 1 identifies patterns of adoption disaggregated by head of household, as well as the common input requirements and challenges to implementation.

Off-farm adaptation practices

Off-farm services, such as early warning systems, extension and training, credit facilities, storage facilities, and market information are offered to farmers to increase their climate adaptive capacity. Such services are offered by a variety of actors, from government (such as the meteorological, veterinary, agriculture, fisheries and livestock departments) to organizations like KRCS, World Vision (WV). Participatory scenario planning meetings are organized every season, bringing together key stakeholders under the guidance of professional experts who assist in collectively finding ways to interpret the information (both local and scientific knowledge) into a form that is locally relevant and useful. For instance, the Kenya Meteorological Department (KMD) provides weather forecasts for the expected rainfall; the Department of Agriculture (DA) and ASDSP have information about specific crops' water requirements or the ideal type of the seed for the season; the Department of Livestock (DL) gives marketing advice; the Department of Veterinary Services (DVS) offers advice on interventions for managing expected diseases and pests. Uniting all this expert information, a dissemination plan is compiled and transformed into a version that can be broadcast on the radio in the local language and field barazas. In addition, these departments might follow up their recommendations by providing the following services, amongst others: agricultural extension, weather and climate information, early warning systems, market.

Agricultural extension officers sensitize and train farmers on sustainable land management practices such as intercropping, conservation agriculture, terracing, water harvesting, composting, and agro-ecological crop selection (e.g. sorghum for drought tolerance). Extension agents play a key role in the adoption of improved farming practices and adaptive mechanisms. Early warning systems enable farmers to know when and where to plant, and when to move livestock, based on information on expected drought and floods occurrence which can affect crop and livestock production. The KMD is responsible for the county's weather early warning systems. Daily, weekly, monthly, seasonal forecasts are generated by KMD in integrating scientific and traditional knowledge. This information is then shared and distributed through emails, SMS, public barazas, pamphlets/brochures, broadcasted on local radio in local language and TV The majority of the population has access to radios, making it an effective means of transmitting information.

Climate smart advisories are offered by the department of Agriculture, Livestock and Fisheries with the support of key stakeholders such as ASDSP, KDFF, Hand in Hand East Africa, SDCP, KWEN. Agro chemicals and seed companies such as KFA. They have information about specific crops' water requirements or the ideal type of the seed for the season, marketing advice, and advice on interventions for managing expected diseases and pests. These advisories are important in promoting preparedness among the farmers and the expected outcomes from the early warning information from the KMS.

The department of agribusiness is key in providing agricultural extension services that are supported by agricultural research and appropriate technology to farmers, regulation and quality control of the sector's inputs and products as well as improving their access and the support of the management and the control of pests and diseases in crops. The department of livestock provides the extension services to farmers on good production systems that are linked to the climate weather advisories. The DVS also support the management and control of pest and diseases in livestock and the management and conservation of the natural resource base for livestock production. The department of fisheries also provides extension services through field days, fish eat campaign[32]. Private Service providers also provide extension services such as the seed companies and agro dealers. Another key off-farm adaption option that is not exploited in the county is that of insurance services offered by the various financial institutions. There is the need for sensitization on the importance of this adaptation tool. This can ultimately benefit the farmers against climatic hazards and their consequences. It was clear that majority of the farmers are not aware of this adaptation option.

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31 Majorly in the vernacular radio stations such as KASS, majority of the population have access to radio in their households.
32 Teach the fish farmers how to prepare the fish so as to promote fish intake in the county.

Adapting agriculture to changes and variabilities in climate: strategies across major value chain commodities

Banana

	Provision of seeds and other inputs	On-Farm production	Harvesting storage and processing	Product marketing
Moisture stress/ droughts	Delayed acquisition of planting materials; Delayed acquisition of inorganic fertilizer till onset of rains; Prolonged land preparation, digging of holes due to hard ground	Poor bunch formation, lower number and small sized fingers resulting	Reduced weight, bulking quantity and value of product. High post-harvest loss. Higher transport cost in relation to product value	Accelerated fruit ripening and decay during transportation. Low prices due to low quality and quantity of produce. Inconsistent supply resulting in difficulty in securing markets. Low revenues and profits for farmers
Magnitude of impact	Major	Major	Much	Severe
Farmers' current strategies to cope with the risks	Application of farm manure to help conserve soil moisture during dry spells	Manual irrigation using water buckets and watering cans	Spraying of water on harvested produce to reduce perishability and prolong freshness	Exploring multiple markets (mostly individually)
Other potential options to increase farmers' adaptive capacity	Application of plant organic matter as mulch to help conserve soil moisture and protect seeds and seedlings. Mechanised land preparation. Early land preparation	Use of modern low-cost irrigation systems such as drip, flood and sprinkler irrigation. Use of in-field water conservation practices to conserve soil moisture (pits, mulching, minimum tillage)	Use of improved storage facilities with appropriate moisture/ RH regulation. Storage in common facilities through cooperatives	Use of improved storage, transportation and preservation techniques to prolong quality of produce. Bulking and collective marketing through cooperatives
Uncertainty of seasons (onset and duration)	Wilting and loss of suckers. Delayed acquisition of inputs. Increased storage costs for inputs	Some areas may experience hardpans, affecting land preparation; delayed planting due to inadequate soil moisture; delayed weeding	N/A	Inconsistent supply resulting in difficulty in securing markets. Change in season can affect production quality and quantity and hence income. Missed market opportunities
Magnitude of impact	Moderate	Major	Moderate	Severe
Farmers' current strategies to cope with the risks	Use of manual irrigation	Postpone land preparation; delayed planting	Harvest crop early in the morning to reduce shattering (pods splitting open); immediate disposal of the produce	N/A
Other potential options to increase farmers' adaptive capacity	Application of plant organic matter as mulch to help conserve soil moisture and protect seeds and seedlings. Mechanised land preparation for timely planting. Early land preparation. Enhanced use of agro-meteorological information	Use and adoption of appropriate early maturing varieties	Use of improved packaging and storage facilities with appropriate moisture/ RH regulation. Storage in common facilities through cooperatives	Enhanced use of marketing information system. Collective marketing

Irish Potato

	Provision of inputs	On-Farm production	Harvesting, storage and processing	Product marketing
Drought/ Moisture stress	Creation of hardpan during land preparation. Inadequate availability of seeds particularly from accredited seed suppliers (sometimes costly or not locally available). Low quality seeds	Cost of land preparation is high due to need for use of machinery. Vulnerability of crop to pests and disease	Wilting and moisture loss during storage resulting in low weight and quality. Reduced quality and shelf life of the product	Low prices due to low quality of produce. Susceptibility to middlemen who pay low prices. High transport costs compared to product value
Magnitude of impact	Moderate	Major	Moderate	Moderate
Farmers' current strategies to cope with the risks	Carry-over of seeds	Incorporation of organic manure into the soil to help conserve moisture	Use of appropriate packaging materials to control moisture loss while minimising susceptibility to rotting	Sales to middle men
Other potential options to increase farmers' adaptive capacity	Capacity building and licensing of community seed suppliers to ensure supply of high quality seeds	Use of agro-meteorological information to improve farm decision making. Use of drought or flood resistant varieties. Use of conservation agriculture practices (mulching) to conserve soil moisture	Strengthen cooperatives to acquire cleaning and sorting machinery. Construction of improved storage facilities with appropriate moisture regulation mechanisms. Invest in value addition and processing facilities	Strengthen marketing associations and cooperatives to add value; improve market information platforms; contract farming to protect from total financial losses. Introduction of agricultural fairs
Intense rains	Pests and diseases affecting seeds. Water damage to stored inputs. Transport of input supply can be hampered	Difficulty in land preparation due to water logged fields. High incidence of pests and diseases (e.g. leaf blight)	Difficulty in harvesting from water logged fields. Rotting of produce. High perishability during storage due to excess humidity	High transportation costs due to low accessibility (e.g. flooded roads). High rainfall could lead to more production hence market glut; low prices due to high supply and few market options
Magnitude of impact	Moderate	Moderate	Moderate	Moderate
Farmers' current strategies to cope with the risks	Carry-over of planting materials	Early land preparation and planting. Spraying with fungicides	Timing harvesting to coincide with reduction of rains. Covering of product with grasses and polythene papers. Harvested tubers are left to dry before selling/storage	Selling through middlemen. Transportation by bodaboda or smaller vehicles when large roads are impassable
Other potential options to increase farmers' adaptive capacity	Capacity building on appropriate storage and management of seeds. Use of organic pesticides and disease control methods for seeds. Training on use of high quality, certified seeds	Use of conservation agriculture practices to manage infield water. Use of IPM to manage pests and diseases. Use of flood resistant/tolerant varieties	Mechanized harvesting, cleaning and sorting. Construction of improved flood proof storage facilities	Improvement of rural road networks. Improvement of market information using cell phones and social media

Sweet potato

	Provision of seeds and other inputs	On-Farm production	Harvesting storage and processing	Product marketing
Moisture stress/ droughts	Reduced availability and quality of planting materials	Hard ground makes tillage difficult. Low size, quality and strength of tubers	High collection and transportation costs in relation to low value of produce	Low prices due to low quality of produce. Susceptibility to middlemen who pay low prices. High transport costs compared to product value
Magnitude of impact	Severe	Moderate	Moderate	Moderate
Farmers' current strategies to cope with the risks	Obtain planting materials from previous crops/vines	Communal land preparation. Spreading of animal manure during the dry period to be absorbed when rains fall. Intercropping sweet potato with maize. Bucket irrigation	Low quality produce is consumed at the household level. Delayed harvesting	Sales to middle men. Sales from individuals to individual
Other potential options to increase farmers' adaptive capacity	Establish bulking/seed plots of improved varieties	Provision of subsidized tractor services by the county government. Strive to do early land preparation when the soils are still wet. Compost production to enhance soil fertility, reduce hardpans and improve water holding capacity. Establish small scale irrigation. Infield ridges for water conservation. Use of drought resistant varieties	Construction of cold storage facilities. Farmers to be trained on appropriate pre- and post-harvest handling and storage. Mechanized cleaning and sorting	Collective marketing through cooperatives
Uncertainty of seasons (onset and duration)	Uncertainty in timely availability of planting materials	Wastage of inputs such as seed and fertiliser due to untimely application. Difficulty in planning farm activities	Low yields. Poor quality, low weight produce. Greater storage costs and more labour required for harvest	Difficulty in collective marketing due to differences in maturing date and low quality produce. Low prices due to low yield and quality
Magnitude of impact	Moderate	Moderate	Moderate	Minor
Farmers' current strategies to cope with the risks	Obtain planting materials from previous crops/vines	Land preparation and planting are done concurrently	Low quality produce is consumed at the household level. Delayed harvesting	Quick sales of produce once it has been harvested in an uncoordinated manner between farmers
Other potential options to increase farmers' adaptive capacity	Establish bulking/seed plots of improved varieties. Extension agents to visit farmers early before the rains start. Improved agro-meteorological information	Prepare land in advance of the season and long before planting	Proper sorting and grading of harvested crops	Collective marketing and synchronised harvesting to increase volumes and pursue larger more profitable markets

Chicken (local)

	Provision of seeds and other inputs	On-Farm production	Harvesting, storage and processing	Product marketing
Moisture stress/ droughts	Local feed shortages and price increases. Chick parasites and disease due to drought	Bird deaths. Low production (weight and eggs) due to malnutrition and heat stress. Increase in disease incidence	Reduced shelf life of eggs. Reduced quality and size of eggs and chickens	Supply not able to meet demand
Magnitude of impact	Moderate	Moderate	Major	Moderate
Farmers' current strategies to cope with the risks	Use of local crop residue and waste as feed	General livestock health promotion. Use of homemade enclosures to protect chickens from outside weather	Destocking	Selling poultry and poultry products locally; individual to individual sales using locally made cages
Other potential options to increase farmers' adaptive capacity	Training on improved homemade poultry feeds and supplementation	Improved hatcheries and chicken enclosures	Establishment of modern chicken and egg collection, storage and processing facilities	Collective marketing and contract chicken and egg farming; use of improved chicken cages. Establishment of market information systems
Intense rains	High chick disease prevalence. High mortality rate of chicks. Feed spoilage due to high moisture	High incidences of endo-parasites and chicken disease. Contamination of chicken enclosuress	Higher perishability of chicken and chicken products. Storms can cause power cuts which affect cold storage facilities	Supply not able to meet demand. Impassable roads make marketing difficult
Magnitude of impact	Major	Severe	Moderate	Moderate
Farmers' current strategies to cope with the risks	Sun drying of feeds to avoid losses	Irregular deworming and vaccination. Use of multiple and synchronised hatching	Prompt sales of chickens and eggs (destocking)	Individual sales at local market or to vendors
Other potential options to increase farmers' adaptive capacity	Use of modern feed storage facilities to protect from moisture	Regular deworming and vaccination combined with modern chicken cage rearing systems. Regular sanitation of chicken enclosures. Use of modern hatching and brooding systems that protect from water intrusion	Improved storage facilities that protect from flooding. Use of mechanised processing equipment. Establishment of modern collection centres	Organise group marketing; establish market information systems; Improve road networks

Policies and Programmes

Several policies and programs aimed at broadly addressing topics related to climate vulnerabilities have been put in place through the collaboration of local and international, public and private actors along with the community at large. Some of the policies that are being implemented in Bomet County include the national statutes and strategies, International conventions and local policies, there are efforts to domesticate some of these policies; these efforts have not been completed yet. Some of these policies and programs include *inter alia*:

The Climate Change Act, 2016 has been enacted by the legislature; the act provides a framework for funding operation and mitigation of climate change issues both at the national and at county level. The Forest Act of 2005 contains several innovative solutions to rehabilitate degraded sites and support the planting of trees nationwide. There is a strong emphasis on partnerships, the engagement of local communities, and promotion of private investment. KFS Bomet cooperates with the farmers groups and communities to implement activities related to forestry[33] and ecosystem conservation[34], protection of Chepalungu forest. The Forest Act acknowledges forest community associations as important partners in forest management. Nonresident cultivation formerly known as the Shamba system is ongoing in the county through 13 CFAs[35] in Chepalungu forest[36]. This helps to improve livelihoods while at the same time protecting the forest. The main challenge to implementation and adoption is the lack of community participation.

The Environmental Management and Coordination Act (EMCA) of 1999 was amended in 2015, including climate change considerations on the agenda. It guides ministries to consider climate change mitigation measures in their actions and budgets, requesting the establishment of environmental departments or designated officers in each County. Department of Environment and NEMA in Bomet County are the key implementers of this statute. County Environmental Action Plan (2013-2018) is implemented by NEMA in accordance with the provisions of the Environmental Management and Coordination Act (EMCA) of 1999 Section 40. The CEAP is an important tool in integrating environmental concerns in implementation of county project, programmes, millennium development goals (MDGs) and sustainable development in general.

ASDS (2010-2020) seeks to progressively reduce unemployment and poverty, and to spur agricultural growth. The vision of the ASDS is a food-secure and prosperous nation. Since the agricultural sector is still the backbone of Kenya's economy and the main source of livelihood for most of the rural population, it is key to food security and poverty reduction. The overall development and growth of the sector is anchored in two strategic thrusts: increasing productivity, commercialization and competitiveness of agricultural commodities and enterprises and developing and managing key factors of production. The ASDSP Bomet aligns its operations and interventions to this strategy.

The Crops Act, 2013 seeks to accelerate the growth and development of agriculture, enhance productivity and incomes of farmers and the rural population, improve investment climate and efficiency of agribusiness and develop agricultural crops as export crops. Department of Agribusiness, Livestock, Fisheries, value addition, cooperatives and marketing carries out its interventions aiming to meet the expectations of this act. Lastly, Vision 2030 has identified agriculture as one of the key sectors to deliver the 10% annual economic growth rate envisaged under the economic pillar. To achieve this growth, transforming smallholder agriculture from subsistence to an innovative, commercially oriented and modern agricultural sector is critical.

The Agricultural Sector Development Support Program (ASDSP) is a program funded by the Governments of Kenya and Sweden whose objectives is to transform Kenya's agriculture into an innovative, commercial oriented, modern industry as part of a larger strategy to alleviate poverty and improve food security. In Bomet County, the ASDSP is involved in the facilitation and coordination of the participatory scenario planning with the key stakeholders such as the Kenya Meteorological Department, The Indigenous Knowledge systems, NEMA, Dept. of Agribusiness cooperatives and marketing, media-vernacular radio and TV such as KASS FM, KASS TV, Chamge FM. The ASDSP has been funding the Participatory Scenario Planning (PSP) with the help of KMD while the Department of Agribusiness cooperatives and marketing disseminates the advisories through barazas.

The ASDSP also works with key value chains actors, including farmers and county departments, towards developing and strengthening value-added practices in the Dairy, Local Chicken, Irish potatoes and maize. The value chain development had a thematic, technical working group. County steering committee and later validated in workshop. The program also focuses on environmental resilience and social inclusion, institutional and capacity development. Challenges that ASDSP faces include lack of infrastructure such as value addition infrastructure,

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33 Issue grazing and monthly fuel license through the CFA, KFS charges sh.100 per cow p.m. and sh.100 per month respectively.

34 KFS Bomet issue permit for transportation in the event of tree cutting->4 tones one is charged 1000, <4 tons is equivalent to shs.1500, >10 tons is equivalent to sh.2000.

35 ASDSP reports that the county has 13 established CFAs and accrues benefits from forest products such as, timber, honey, fire wood, building materials, herbal medicine, pottery clay, grass and pine gum.

36 One acre they charge KES 1000, 0.5 acre they charge KES 500.

marketing infrastructure to compliment the capacity building that they engage in. Finance is also a challenge, the farmers on the value chain under ASDSP get the support, however, not only these farmer groups and cooperatives need assistance, other farmers engaging in other value chain also need financial support. ASDS was drafted before the devolution and agriculture is devolved thus the county specifics is undermined.

The Bomet Integrated Development Programme is 3 year programme started in the financial year 2014/2015 and expected to end in 2017. It is a joint project that is co funded and implemented by the County Government of Bomet and Kenya Red Cross Society (KRCS) which contributes towards the improvement of quality of the residents of Bomet County for sustainable development. The project is achieved through key interventions aimed at contributing to improved Water Sanitation and Hygiene (WASH), Water supply and irrigation, nutrition and Agribusiness geared towards food security and livelihoods. In the water supply and irrigation component, the main aim is to supply water to 55,000 beneficiaries in Bomet Central and Cheplaungu Sub-Counties. The intervention is geared towards provision of clean water, health, nutrition and food security in a multi-disciplinary approach, in areas of good farming practices, environmental conservation, and use of clean and safe water. There are 2 irrigation schemes namely Chebaraa irrigation scheme benefiting 1200 farmers and Nogirwet irrigation scheme benefiting 800 farmers. KRCS support farmers with farm inputs such as drip kits, fruit seedlings and vegetables such as tissue culture bananas, grafted mangoes and avocadoes, agro chemicals. They also train farmers on how to efficiently use these farm inputs, they teach sustainable land management practices and provide extension services. The challenges linked to this programme are the blockages of the main pipes and inadequate funding to reach more beneficiaries.

The Livelihoods and Resilience Project is spearheaded by the World Vision in partnership with the county government of Bomet. The focal area of operation is in Chepalungu Sub-County, the hot and dry agro-ecological zones in Chebonyo, Cheleget, Saboson, Kamaget, Lelaitich and Mogor locations. The main objective of this project is to promote resilient communities and its goals include, enhancing eco-empowerment through youth groups, women and men saving groups, training in entrepreneurial skills, vocational training, improving food production mainly nutrition among mothers and children where WV works with farmer groups and mitigate against climate change extremities through disaster reduction[37]. World Vision promotes Climate-Smart Agriculture (CSA) practices such as drip irrigation, small kitchen gardens establishment and maintenance and support in conservation agriculture. World Vision also trains the farmers on these climate smart practices in farmer groups and provides market linkages in partnership with the marketing and cooperatives department; it supports the farmers with machinery and equipment in value addition of milk[38] and sweet potatoes[39]. In carrying out its intervention on climate risk management, WV has experienced major challenges such as the inadequate road network of the county resulting in milk from farmer groups going bad and thus leading to post-harvest losses and affecting the output market stage.

Kenya Agricultural Value Chain Enterprises (KAVES) works with smallholder farmers, businesses, national and county government partners to address constraints in the entire value chain to develop fully-functioning, competitive value chains. In Bomet, this program started in early 2014 and its duration is 5 years. KAVES in Bomet aims to increase the productivity and incomes of smallholder farmers, and other actors along the value chain, who are working in the dairy, maize and beans[40] and horticulture sectors by promoting good agricultural practices such as promoting mechanization, threshing, use of herbicides, use of hermetic bags to prevent post-harvest losses, promoting hydroponics or feed formulation, promote AI, by working with different stakeholders such as CGA based in Sotik that is engaging in maize value chain, EAMDA that is working in the 3 Value Chain. The activity develops smallholder enterprises that combine maize, high-value horticultural crops and dairy farming to generate wealth, thereby enhancing food security, improving nutrition and increasing economic opportunities for women, youth and other vulnerable populations. In Bomet, they work with vulnerable women groups such as Samaria Kisabita and other key stakeholders such as PAFID in conservation agriculture in Bomet East in Kapkimolwa and Chepalungu.

Small Holder Horticulture Marketing Programme (SHoMaP) Mogogosiek market/Konoin is a programme started by the County Government of the Bomet with the aim to increase incomes from horticultural production for the domestic market, to increase employment opportunities in the production, processing and marketing of horticultural produce; to reduce the cost to consumers and design and construction of fresh produce market infrastructure (market stalls, stores, toilets, and fencing). Other key programs in the county include East Africa Dairy Development programme (EADDP) under Heifer International and various projects initiated by the county government and implemented by the various departments in line ministries.

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37 In most cases drought.
38 Value addition of milk include yoghurt, mala and the traditional *mursik*
39 Value addition product is sweet potato crisps.
40 Classified as staples.

Policies and programmes are key considerations for agriculture decision making, since they affect actions and outcomes related to resource use. Tackling the impacts of climate change and ensuring that agriculture is aligned with climate-compatible practices is of the utmost urgency. Concerted efforts at the farm, community and national levels are necessary to deploy a variety of solutions, interventions and instruments to address the impacts of climate change on agriculture. Climate challenge to agriculture requires adaptation solutions that could extend beyond the scope of current agricultural techniques and farmers systems. Mainstreaming adaptation to agriculture is a dynamic process that goes beyond introducing new agricultural techniques that must also cover institutional reform, policy and regulatory mechanisms as well as harness market-based instruments.

Governance, institutional resources, and capacity

Institutions are key considerations for agriculture decision-making since they shape actions and outcomes related to resource use. In agriculture, the role of institutions can be related to the design of policies and investment frameworks, knowledge development and sharing, technological development or the delivery of financial and non-financial incentives for agricultural investments (FAO, 2010). Bomet County has several institutions actively involved in climate-related issues, ranging from county government institutions (Department of Agribusiness, Livestock, Fisheries, Value addition, Marketing, Cooperatives, Department of Water, Environment and Natural Resources) to national government institutions such as NEMA, KMS, KFS to non-government to the private sector (agro dealers, financial institutions) and community based organizations and cooperatives. Bomet County is also home to many Savings and Credit Cooperative Societies (SACCO) whose main focus is agriculture and microcredit. There is a department within the agribusiness that is managing the cooperatives in the county[41]. There are micro finance institutions such as Kenya Women Finance Trust (KWFT) that aims to empower women economical. Some of the key institutions are discussed below.

County governments are the main providers of agriculture and livestock extension services while the national government formulates policy, develops extension services delivery standards, and builds capacities of service providers. Other extension service providers include agro-veterinary pharmaceutical companies, animal feed manufacturers, milk processors, Non-Government Organisations, and Community-Based Organizations. NEMA's key function is to coordinate the institutions that are dealing with the management of the riparian land through the county environment committee and coordination of various environmental projects. NEMA is key in rehabilitation of Chepalungu forest, where 50 acres has been fenced to protect it. Enrichment of 25,000 seedlings (insitu) where they plant indigenous species. They collaborate with CFA and the community in general and key stakeholders such as KFS. However, NEMA faces a lot of challenges such as inadequate finance, human capital; the awareness level among the communities is low as the communities are not receptive to new technologies.

The Kenya Forest Service (KFS) is a semi-autonomous government parastatal, implementing activities related to climate change, forestry, forest conservation, and ecosystem conservation. It works with NEMA, CFAs, county government and other key stakeholders to finance and monitor projects in ecosystem conservation. KFS engages in tree planting, such as the afforestation project in Chepalungu forest, conservation of the catchment areas[42] by providing extension services and technical advice. KFS works closely with the CFAs in the county through non-resident cultivation formerly known as the Shamba system in Chepalungu forest that helps in livelihoods improvement[43] and at the same time forest conservation. KFS' tree planting initiatives face some community resistance, as the efforts are not self-driven and communities do not always see the direct benefits. Lack of adequate funds, climate related risks such as reduced rainfall curtailing their tree planting interventions and consequently challenging efforts to increase the forest cover in the county.

The Kenya Meteorological Department (KMD) generates daily, weekly, monthly and seasonal forecasts through data analysis and workshops held with key stakeholders, including indigenous weather forecasters and relevant departments. Through Participatory Scenario Planning (PSP) the experts develop a dissemination plan that may include components such as information sharing through the ASDSP environmental resilient officers, Emails, SMS, brochures, public barazas, radio station and TVs in vernacular stations such as KASS and Chamge FM. Many of the entities or institutions that collect environmental/climate data work independently and in isolation, often failing to share data or to collaborate in a way that would support and enable the creation of better, more relevant information. The lack of adequate equipment such as rain gauges in the county, understaffing and insufficient funding challenges KMD's capacity to implement activities.

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41 There is a multipurpose cooperative society in the 30 wards in the county that comprises farmer groups, small medium enterprises that are well organized. They are under the Bomet County Cooperative Union that is the umbrella of all the cooperatives in the county.

42 Mau Natural Forest Complex that lies administratively in Narok County.

43 This is through proving land for tilling, grazing animals and for fuel wood for cooking. They achieve this through issuing permits.

Kenya Red Cross Society (KRCS) is a humanitarian organization established under Cap 256 of the Laws of Kenya as the National Red Cross Society in Kenya. The Society is auxiliary to public authorities in the humanitarian field with an objective to prevent and alleviate human suffering throughout the territory of Kenya. In Bomet, it operates in the lowlands of the county, in Chepalungu. Through the BIDP it carries out its mandate through the five components of WASH, Water supply and irrigation, Nutrition and Agribusiness through food security and livelihoods expounded above. The challenge KRCS experience is inadequate funding to reach more beneficiaries. World Vision is a global Christian relief, development and advocacy organization dedicated to working with children, families and communities to overcome poverty and injustice. World Vision serves all people, regardless of religion, race, ethnicity, or gender. Its area of jurisdiction in Bomet County is in the lowlands of Chepalungu in the 6 locations in the livelihoods and resilience program mentioned above. As earlier indicated, the poor road network curtails their climate related interventions.

Agro-veterinary companies such as Kenya Seed Company, KFA, KEPHIS, engage in the distribution and sale of agro-chemicals and other farm inputs and often train farmers on the safe usage of pesticides, fertilizers and other input supplies.   They include: Financial institutions such as AFC and banks (Equity Bank, Cooperative Bank, Kenya Commercial Bank, National Banks) provide loans to farmers to purchase the inputs needed for the production and storage of produce. The extent to which such formal financial institutions are accessible and used by farmers is yet to be clear. With cooperatives, farmers can pool production from their individual farms in order to meet market demand, reduce risk, access better financing, acquire and share farm machinery and other assets, value addition, negotiate better prices, and jointly market their produce. Cooperatives in the county vary in size and influence. The Department of Cooperatives in the county is actively involved in this devolved function. Every ward in the county has one or two multipurpose cooperative societies[44]. The umbrella of the 30 multipurpose cooperative societies is the Bomet County Cooperative union that has a sweet potato plant. About 80% of the cooperatives are organized and structured to carry out their mandate. The challenge faced include, the governance of these cooperatives due to political interference and the climate related risks affecting the prices of the agricultural produce and thus affecting the operations of the cooperatives.

Factors affecting agricultural industry are low rate of technology adoption, underdeveloped supporting services and inadequacy of information among other factors. For value addition institutions, the challenge was mainly as a result of environment and climate change that affected quantity and quality of produce thus inhibiting value addition services. Strong research and extension institutions are key in enhancing competitiveness in the agricultural industry and increasing agriculture and livestock productivity. The main constraints in research and extension service delivery within the agriculture and livestock sub-sector include low investment in agricultural research by public and private sectors, inadequate attention to post-production research, particularly value-addition and marketing, and inadequate facilities for dissemination of the research findings. The county government in liaison with all the relevant stakeholders needs to strengthen early warning systems to enhance drought preparedness and mitigation.

Synthesis and Outlook

Increased frequency and severity of climatic shocks such as drought, floods, heat stress and uncertainty in the start and duration of the growing seasons all have negative impacts on agriculture and food security. There is an urgent need to implement adaptation measures that can help farmers reduce their vulnerability and cope with the adverse consequences of climate change. This involves both short-term and long-term adaptation strategies.

In Bomet County, where dairy production is a major livelihood activity, farmers have not exploited Biogas technology fully due to both limited awareness as well as insufficient income from farming activities. Biogas utilization at household level will result in both economic and non-economic improvements. The anticipated economic benefits will include saving cost on fuel, reduction in the amount of wood extraction, increased revenue and employment creation. No carbon trading initiatives have been introduced so far. However, there are opportunities for carbon-related projects in Bomet County given the large vegetation cover in the Mau, Chepalungu forest and private forests. There is a need to integrate environmental conservation, for instance, in the case of vaccination, proper disposal of tins and plastics. With the low farmer to extension officer ratio in the county, the viable opportunity option is to improve link between extension officer& farmers for better technology development, transfer & adoption. This can be achieved through increased personnel and capacity building and training.

There is a need for an enabling policy framework in the county. Bills such as the Bomet animal welfare bill, Bomet County animal disease bill, Tea bill, Crops

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44 Currently, there are 30 multipurpose cooperative societies in the county.

agriculture bill (2016), Irish potato policy draft, input subsidy policy draft, crop protection policy draft are still in the county assembly. There is need for prioritization and enactment of these bills and policies so they can be fully functional and meet the needs of agriculture and ultimately climate change. Increased cases of human wildlife conflict in the communities bordering the forest indicate the need for a tailored policy on how to intervene on these matters. There is also need to strengthen the capacity of KMD) so as to strengthen weather monitoring, early warning, and drought warning systems and extend it to crop yield forecasts by providing the necessary skills, funds and capacity building at the community level.

The government policy on subsistence crop improvements is not adequate hence the limited work being done in this area compared to commercial agriculture. Both human and financial capacities are inadequate to support new institutions at county level in the service delivery necessary for adaptation to climate change. There is need for policy reform to encourage individuals, groups and private companies to take advantage of good seasons by creating good and reliable business environment that may improve access to agricultural inputs and technologies. There is need to address factors hindering the wider adoption of available technologies which could be beneficial to poor households to improve their returns on agricultural investment. There is, however, a commitment to improve research and development, strengthen the human and financial capacities of research institutions and strengthen collaboration between research, policy and public-private partnerships.

Attention should be placed on identifying and introducing a climate-compatible strategy or new policy or improve existing policy or program that is tailored to the agricultural sector under evaluation, but which is in line with a broader national policy and cross-sectoral climate change strategy. Improving the enabling environment through policy action and governance reform for climate adaptation also requires synergies that are horizontal (across ministries and government agencies) and vertical (between public and private sectors, especially between government and vulnerable stakeholders, including small-scale farmers, women and young groups). Required interventions may also require putting in place market-based mechanisms or policy driven economic incentives to encourage the uptake of adaptation best practices. Implementation may also require policy dialogue resulting in institutional reforms and new governance structures that are necessary to achieve climate adaptation and sustainability.

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Investigation of Maize Lethal Necrosis (MLN) severity and cropping systems mapping in agro-ecological maize systems in Bomet, Kenya utilizing RapidEye and Landsat-8 Imagery

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Investigation of Maize Lethal Necrosis (MLN) severity and cropping systems mapping in agro-ecological maize systems in Bomet, Kenya utilizing RapidEye and Landsat-8 Imagery

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ABSTRACT

Spatiotemporal information on crops and cropping systems can provide useful insights into disease outbreak mechanisms in croplands. In September 2011, a severe outbreak of Maize Lethal Necrosis (MLN) disease was reported in Bomet County, Kenya. We aimed to detect severely MLN-infected fields and discriminate mono, inter, and continuous maize cropping systems. We collected in-situ MLN severity observations and acquired multi-date and multi-sensor data viz., RapidEye (RE), Sentinel-1 (S1), digital elevation model (DEM), and Landsat-8 (L8) imagery. A hierarchical classification approach was used to map the cropping systems and severely MLN-infected fields during the short rainy season (September 2014–February 2015) using the random forest (RF), one-class support vector machine (OCSVM) and biased SVM (BSVM) classifiers. RF showed better performance when a balanced multi-class dataset was available. Both OCSVM and BSVM did not lead to an accurate high severity MLN class separation. Moreover, the BSVM classifier was able to separate the mono and intercropping systems. During the long rainy season (March–August 2015), only maize crop data were available, hence the BSVM as one class classifiers (OCC) was used and maize fields were successfully mapped even with high confusion rate. Furthermore, the distribution of maize intercropping system increased in low rainfall sites, and the continuous cropping system limited to only 31% of total maize cropland.

1. Introduction

Maize farming is the backbone of food and nutrition security in Kenya. The area under maize in the country increased from 1,700,000 ha in 2008 to 2,159,322 ha in 2012, which is the highest maize area increment since 1961. Maize production in Kenya also increased from 1,382,643 tons in 2012 to 3,513,171 tons in 2014, although the country still imports tonnes of maize from neighbouring countries like Tanzania each year to meet the consumption gap (Indexmundi, 2019). In general, maize production in eastern and central Africa is threatened by many biotic and abiotic constraints. One of the challenging maize production problems in this region is the Maize Lethal Necrosis (MLN) disease. The disease is caused by the co-infection of Maize Chlorotic Mottle Virus (MCMV) and the cereal viruses in the Potyviridae group such as Sugarcane Mosaic Virus (SCMV), Maize Dwarf Mosaic Virus, or Wheat Streak Mosaic Virus. SCMV is prevalent in Africa for nearly 50 years, but MCMV is much more recent and more destructive compared to SCMV (Braidwood et al., 2017). Also, Johnsongrass

Mosaic Virus which has recently known to be present in the eastern Africa contributes to the emergence of the MLN disease in the region (Stewart et al., 2017). In combination, these viruses rapidly produce a synergistic reaction called MLN. It seriously damages or kills the infected maize plants at any growing stage (Kiruwa et al., 2016). MLN disease is not particularly new and has been identified for first time in the United States of America in 1976 (Nault et al., 1978).

The foremost problem is the fact that MLN outbreaks threaten food and nutrition security in eastern and central Africa. In Kenya, first reports of an unknown disease outbreak were observed in September 2011 in Bomet County. Further virological analyses identified the unknown disease as MLN. This problem has attracted further attention, when in 2012 the maize-crop-losses due to the MLN outbreak reached up to 90% (Mahuku et al., 2015). In 2014, Kipsawet near Bomet County was identified as a MLN hotspot area in Kenya. To overcome MLN outbreaks, different agronomical, biological, entomological, and

pathological management approaches have been tested (Marenya et al., 2018). Planting MLN-free maize seeds, introducing MLN-resistant maize varieties, and practicing maize crop rotations have been proposed to surmount the problems caused by MLN, although the disease cannot be completely eradicated. Osunga et al. (2017) studied the relevance of some ecological variables on the spatial distribution of MLN disease in Bomet County using spatial regression modelling routine. With exception of temperature, they found that soil moisture, rainfall, and slope were the most influential variables on MLN occurrences. MLN disease is not only influenced by ecological variables, but other factors such as maize cropping system (i.e. mono, intercropping, continuous, and rotation cropping) which are reported to play a major role in the disease incidences, severity, and outbreak (Namikoye et al., 2017). However, only a few studies have focussed on the actual spatiotemporal distribution of MLN utilizing remotely sensed data.

In Bomet, the dominant maize cropping systems consist of mono (maize only), intercropping (maize and legumes such as cowpea or beans) and continuous or rotation cropping systems. In this region, farmers grow different maize varieties at varying planting dates during the growing season. Small-scale and highly fragmented farms is also a common practice in Bomet. These constraints make the MLN disease control difficult in this region. Moreover, discrimination of rain-fed crops from natural vegetation is challenging when both farms and surrounding vegetation are at the same phenological stage. Kiruwa et al. (2016) reported that the diagnosis of low and medium MLN severity based on visual symptoms is ineffective. One limitation in visually discriminating between low and medium MLN severity is that symptoms like stunting and chlorosis can also resemble nutrient deficiencies or maize mosaic disease. Because of this potential limitation, in this paper, the focus of detecting MLN-infected maize was only for high severity infestation levels which could lead to necrosis.

A possible solution to map the complex maize cropping systems accurately in Africa and specifically in Kenya is to use a multi-sensor and multi-temporal mapping approach coupled with robust and effective machine learning classification algorithms (Forkuor et al., 2015; Ianninia et al., 2013; Zillmann & Weichelt, 2014). Previous studies have emphasized that spectral vegetation indices (VIs) can enhance the multi-source crop classification results. Studies have also shown that the normalized difference vegetation index (NDVI), for instance, is sensitive to green vegetation and is not highly affected by other variables such as heterogeneous landscapes, atmospheric and sensor

noises, soil background, or other ground elements in the image pixels (Bannari et al., 1995). It is also well acknowledged that, compared to other supervised image classification methods, random forest (RF) is a powerful and robust classification option to map agricultural fields. The method is a non-parametric machine learning algorithm which has the capability of using continuous and categorical datasets, easy to parameterize, and can deal with outliers in training data and is not sensitive to over-fitting (Horning, 2010). Also, RF performs better when dealing with multi-layers and multi-temporal data-sets (Cutler et al., 2007).

On the other hand, in the lack of sufficient samples, the one class classifier is a smarter choice (Braun & Hochschild, 2015; Heinl et al., 2009; Mack et al. 2014; Whiteside et al., 2011). The present paper addresses the need for providing remotely sensed spatiotemporal information of MLN disease occurrence to develop an effective controlling approach, what so far received less attention in the scientific literature. We looked at the possibility of mapping and linking maize cropping systems to high severity MLN occurrences. Specifically, this study investigated the use of RapidEye (RE) and Landsat 8 (L8) imagery to classify and map maize mono and intercropping systems and areas under high MLN infestation. For this purpose, machine learning RF (Breiman, 1996) and a one class classifier were utilized (Mack & Waske, 2017). We analysed the map of continuous/rotation cropping (in two continuous cropping season) and investigated whether the crop rotation was applied by farmers during MLN outbreaks in the region. Furthermore, for this study, it was of interest to establish the relationship between high severity MLN occurrence the corresponding cropping system and rainfall distribution in the study area.

2. Study area

Bomet County is amongst the seven most high potential maize production zones in Kenya, and agriculture is the main economic activity in the County (Olwande et al., 2009). Bomet county has a population of 875,689 (2019 census), and an area of 1,997.9 km2. The most prevalent crops in Bomet are maize, beans, and cowpeas, while maize plays a major role in terms of food and nutrition security and income generation (Nyoro et al., 2004). The County is located in the semi-humid agro-ecological zone of Kenya and the mean annual maximum temperature is 28°C (Bryan et al., 2013). Average cumulative rainfall ranges from 500 to 2000 mm. Rainfall peaks twice a year in Bomet: in March–May (long rainy season) and in

September–November (short rainy season). The vast majority of farmers in Bomet consider long rainy season to be their main maize cropping season and continuous cropping-system is known as the dominant cropping system in Bomet for a long time. However, during the short rainy season, fewer farmers grow maize (Hassan, 1996). The area under monocropping and intercropping system varies between the short and long rainy seasons (Ochieng et al., 2011). In regions with uncertainties in rainfall patterns, the majority of the farmers intercrop maize with beans. In addition, irrigated farming is also practiced in locations neighbouring the major rivers (Kimani et al., 2004). Specifically, the study area (01°18′16S, 034°52′04E, 00°44′43S, 035°25′23E) (Figure 1) covers 61 × 61 km^2 and the highest elevation is 1,962 m above sea level.

3. Methodology

Prior to other steps, all satellite data were transformed to the recommended map projection (i.e. Universal Transverse Mercator: UTM WGS-84 ellipsoid) zone 36 south (Forkuor et al., 2014). To map maize fields, cropping system, and high severity MLN, a hierarchical classification approach was applied on the multi-sensor, multi-temporal satellite data using RF, one class support vector machine (OCSVM), and biased SVM (BSVM) classifiers. Available datasets were divided into two main cropping seasons, short rainy season (first season) from September to February and long rainy season (second season) from March to August. The peak of the rains is from September to November. As the first step, a raster-stack of RE, L8, Sentinel-1 (S1) and calculated VIs were generated for the short rainy season. During the same season, representative training data were collected using stratified random sampling approach (see section I below for details). Using the VIs, the field data and RF classifier, a general five-class land use and land cover(LULC) map (maize, non-maize, trees, water, and non-vegetation) was produced. Maize pixels were extracted from the classified map and reclassified for high severity MLN, mono- and intercropped maize systems using BSVM.

During the long rainy season, only maize fields' data were available, consequently the BSVM classifier as a One Class Classifiers (OCC) was employed to classify maize fields on L8 imagery. Classified maize pixels during both the short and the long rainy seasons were overlaid, and common fields were mapped as continuous maize cropping system. Further, the inter-relations between-maize-cropping-system and high severity MLN with rainfall distribution were investigated. Figure 2 summarizes our data processing and analysis steps and procedures.

(i) In-situ data

We conducted four field campaigns between January to August 2015 during the short and long rainy seasons, respectively, following a stratified random sampling method. During the first rainy season, three field campaigns (between January to April 2015) were conducted to collect data on different LULC classes (water bodies, grasslands, soil, houses, and tarmac roads), crop type and conditions (physical condition, growth stage, and MLN severity), cropping system (mono/intercropping) and crop rotation (continuous/rotational). During the long rainy season, one field campaign only was conducted on August 2015 to collect reference data on the location of maize fields. All in-situ data were georeferenced using a global positioning system (GPS) of ±3 m error. Polygons spanning 30 × 30 m and at least 5 m away from the edge of each field were sampled to avoid the edge effect. For further inspections of the cropping systems and crop age in the sample polygons, geo-tagged photographs of each cropping system were recorded. Also, in order to minimize the soil background effect on the imagery spectral reflectance, maize fields younger than 3 weeks were excluded from data collection.

(ii) Satellite data

The satellite data consist of 5-meter bi-temporal RE imagery acquired between 9 December 2014 and 23 January 2015 which covered the short rainy season. In addition, 12 cloud-free 30-meter multi-temporal L8 images were acquired between November 2013 and August 2015. The L8 imagery covered both the short and the long rainy seasons. All L8 imagery were downloaded from the Landsat Surface Reflectance Climate Data Records (CDRs) database as Level 1 surface reflectance. Two 30-meter Shuttle Radar Topography Mission (SRTM) digital elevation model tiles and two S1 datasets in Interferometric wide swath mode, with dual VV (vertical transmit and vertical receive)/VH (vertical transmit and horizontal receive) polarizations were acquired for the same time period. The S1 data were utilized to improve classification accuracy (Forkuor et al., 2014).

(a) Pre-processing

(iii) SAR data

The SRTM DEM (digital elevation model) arc 1-sec imagery were cropped and resampled (bilinear interpolation) to L8 and RE imagery. These products were stacked with L8, RE, S1, and VIs to provide an input for RF classifier. In addition, the DEM was needed to perform atmospheric and topographic corrections on RE imagery to reduce the speckles and to geometrically correct the S1 imagery. A Lee filter of 7 × 7 pixels and Range–Doppler Terrain Correction methods were applied according
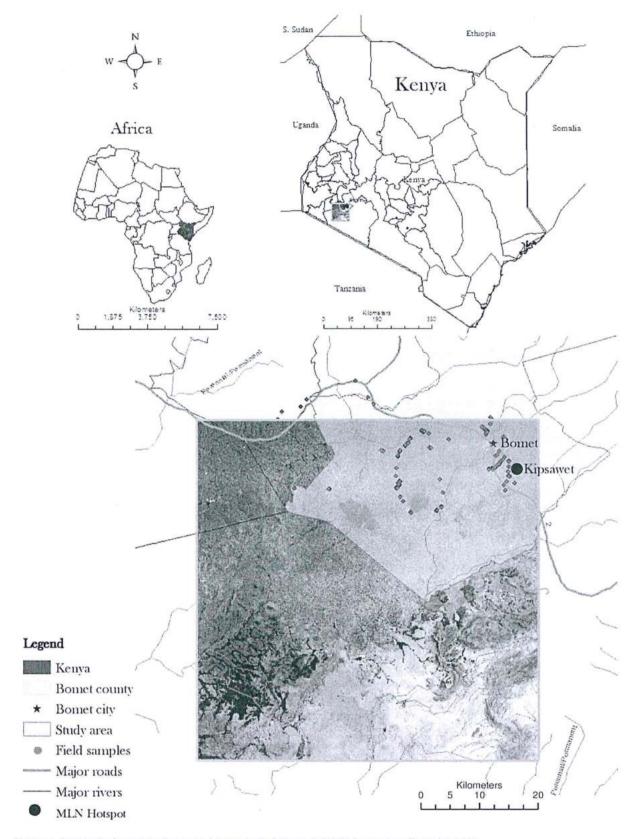
Figure 1. Bomet study area in Kenya and Maize Lethal Necrosis (MLN) hotspots collected in 2015.

to the procedures described in Ozdarici and Akyurek (2010). The filter was implemented by the SNAP software (from ESA) sentinel-1 toolbox using the post-filtering module. . Further, the backscatter of the corrected S1 imagery was converted to decibel (dB) units.
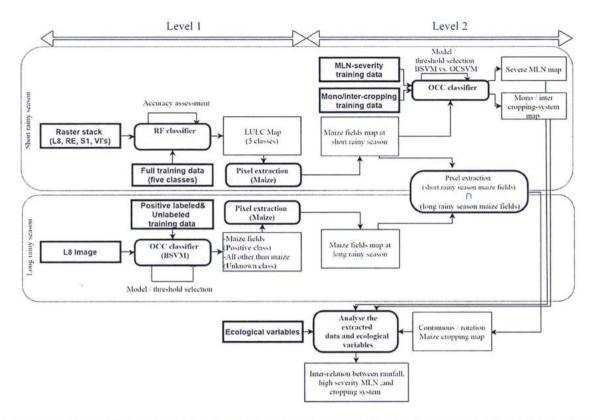
Figure 2. Workflow of the hierarchical classification approach using random forest and one class classifier during the short and long rainy seasons in Bomet, Kenya. The arrows illustrate data flow directions and dependencies, squares represent datasets while rounded rectangles were processes.

(iv) *RapidEye*

The RE tiles were atmospherically and geometrically corrected using atmospheric-topographic correction (ATCOR 3) software which requires SRTM DEM data (Richter & Schläpfer, 2005). Finally, the radiometric-geometric-corrected-tiles were mosaicked to produce a two RE imagery layers' stack for the two different acquisition dates.

(v) *Landsat 8*

L8 imagery were cropped to RE image products, resampled and co-registered. Both RE and L8 imagery had cloud and clouds' shadow cover which were manually masked (Kross et al., 2015).

(vi) *Vegetation indices*

Previous studies have emphasized the importance of VIs for crop classification (Bannari et al., 1995; Zillmann & Weichelt, 2014). VIs are more sensitive to "green" that is chlorophyll active vegetation than the single spectral bands. In the present study, several VIs such as NDVI, simple ratio (SR), red-edge NDVI (NDVIre), red-edge SR(SRre), green NDVI (gNDVI), and modified triangular vegetation index (MTVI2) were calculated using the visible, near-infrared, and red-edge bands of L8 or RE imagery. The original bands were used in combination

with the calculated VIs as an input variables on the RF and other classifiers (Forkuor et al., 2014). The time-series NDVI dataset utilized in our study was extracted from 12 cloud-free L8 images which covered the period from November 2013 to August 2015.

(b) *Classifiers*
(i) *Random Forest*

It has been shown that RF classifier was able to handle large-scale high dimensional data with high/medium spatial resolution (Forkuor et al., 2014; Whiteside et al., 2011). Previous studies have also found that RF could perform better on multi-temporal dataset and is capable of dealing with noisy and highly correlated remotely sensed predictor variables (Braun & Hochschild, 2015). In this experiment, RF was employed to classify a raster-stack of RE, L8, VIs, and S1 which covers the short rainy season in the study area. The RF classifier takes random bootstrapped subsets from a training dataset and constructs several classification trees using each of these subsets. Branches in the trees are often thresholds defined for the measured (known) variables in the dataset. Whereas, leaves are the class labels assigned at the termini of the trees. RF classifier requires optimization of two user-defined parameters, which are

number of trees (n-tree) and number of variables used to split the trees (m-try). The default value of m-try is the square root of the total number of the predictor variables. One-third of the training dataset which is not included in the bootstrapped training sample are left out as out-of-bag (OOB) subset. An OOB error for each tree is computed by predicting the class associated with its in-bag value. This process results in a classification confusion matrix which can be used to evaluate the classification results. Therefore, we calculated overall accuracy (OA), producer's accuracy (PA) and user's accuracy (UA) from the confusion matrix to evaluate the RF classifier performance. We set n-tree to 100, 500, and 1000 to help select the most optimal classification result. RF variable importance was, furthermore used to determine the optimal spectral variables (Kuhn, 2007). We tested RF classification experiments with six imbalanced classes and five balanced classes to produce a general LULC map. The experiment that provided a good fit to the data with the best classification performance was chosen.

(ii) One Class Classifier

Previous studies have emphasized that OCC algorithms have the advantage of coping with incomplete training data to map only one specific class of interest. In contrast to RF, OCC just classifies the target class. In the present study, at the long rainy season, the available sample data were constrained to maize fields. In addition, only one class such as monocropping or high severity MLN were targeted at the short rainy season, which makes the OCC classifier as an optimum classification option. On the other hand, a careful manual interpretation of the diagnostic plots such as the class separation and suitability of a specific threshold is necessary for parameter-setting and evaluation which makes the OCC classifier to be less suitable for operationalization (Mack et al. 2014). In this study, OCSVM as a P-classifier (P represents positive labelled pixels as class of interest) was employed to cope with incomplete datasets at long rainy season. Because of the lack of complete validation samples, the so-called performance metrics are unidentifiable in OCSVM approach. High severity MLN (target class) was employed to train the OCSVM classifier (P samples) for the short rainy season period. In contrast to a common supervised classifier, OCC classifiers reject the classification of a pixel if it does not sufficiently match one of the known classes. Consequently, the map production cost can be significantly reduced. This is particularly important, if a complete reference data are missing and the user is interested in only one or few classes. A serious disadvantage in the case of OCSVM, is the absence of a confusion matrix, because the labelled samples are only available for the "Positive class" of interest, but not for the other classes (Mack, 2017).

OCSVM has been performed in both automatic and manual model-selection mode. P-classifiers such as OCSVM performances are based on 1) similarity measure like the distance between the positive training samples and the target pixel to be classified and 2) the threshold of the similarity measure to identify the target class membership. Insignificant class overlap or uniform distribution of negative and positive classes can lead to an optimum OCSVM classification results. In this experiment, PU-performance metrics (puF) diagnostic plots were extracted and data evaluation performed manually. The puF is based on the true positive rate (tpr) which estimates the probability of classifying positive samples (true positives) out of the positive training samples (the total actual positives). puF plots are based on two parameters: 1) "nu" which sets an upper bound on the fraction of outliers (training examples regarded out-of-class) and a lower bound on the number of training samples used as support vector. Setting "nu" to a large value results in a higher number of outliers. This can cause large false positives rate. 2) "Sigma" is the radial basis function (RBF) kernel that is used in various kernelized learning algorithms, specifically in SVM classification. Gaussian kernel function (K) as a non-linear function of Euclidean distance is:

$$K(x, x') = \exp\left(-\frac{||x - x'||^2}{2\sigma^2}\right)$$

SVM classifier tries to find similarities between x (positive training sample) and x' (pixels to be classified) where $||x - x'||^2$, is the Euclidean distance between x and x' and σ is a standard deviation which determines the width for Gaussian distribution. For a larger σ^2 the Gaussian function will tend to fall off slowly and cause low variance and high bias. For a smaller sigma, the decision boundary tends to be high variance and less biased and cause overfitting. "nu" and "Sigma" parameters should be set manually and changed from one classification to another. Also, manual model selection table provides tpr and Probability of Positive Prediction (ppp). The ppp estimates the probability of classifying a sample as positive out of the unlabelled samples which are derived at the threshold 0 (Θ_0). This paper utilized Bayes' rule for OCC with positive and unlabelled (PU) data. The PU-performance metrics (puF) is related to the F-score and can be derived from PU data. PU area under the curve (puAuc) is related to the area under the receiver operating curve. The model selection table parameters such as puAuc (positive/unlabelled area under curve) and performance metrics were utilized to choose an optimal model. On the other hand, puAuc is a threshold independent parameter, which calculates the performance over the whole range of possible thresholds.

Thus, it also considers unsuitable thresholds. It comprises the density histogram of the predicted image (dark grey), the distribution of positive (dark blue box), and unlabelled predictions (light grey box). These are the predictions of cross-validated, positive, and unlabelled training samples. The light-blue box shows the calibration predictions (the prediction on the positive training data with the model, which trained on the full training data).

BSVM uses training with the class of interest as a positive class, and other class as unlabelled class. With the test set (±test), an accuracy assessment for the binary classification results over the whole range of possible thresholds can be performed.

In this study, confusion matrices and accuracy measures for the given classes were provided for two types of thresholds: 1) Θ_0 which was obtained by the BSVM, and 2) the Θ_{opt} which is the highest K. There was a third map threshold (Θ_{map}) which can be obtained by Bayes' rule, but it is not discussed in this study. Usually, Θ_0 leads to very high PA (less omission or high true positive rate) and very low UA (high commission or false-positive rate), while Θ_{map} improves it. PU-classifiers overcome P-classifier problems by bringing into account the unlabelled data. It gives the target classes a label "Positive" and the remaining classes the label "Negative/Unlabelled." With too few unlabelled training samples it will be impossible to get close to the optimal decision boundary.

Also, in some extends, a user-oriented strategy used to support the handling of OCC according to the work of Mack et al. (2014). The detailed evaluation of the results as it has been described by Mack et al. (2014) is out of the objectives of this study.

4. Results and discussion

The imbalanced model of classifying the six classes (maize, grassland, tree, non-vegetation, water, and non-maize crops) using RF resulted in an OA of 65.1%, K of 0.58, and OOB error of 1.64% with 500 RF trees. When 100 trees were used, the model yielded an OA of 63% and K of 0.56. In theory, more RF trees should produce a better classification result, but the improvement in RF model performance decreases as the number of trees increases (Oshiro et al., 2012). It is worth noting that the gain in the classification accuracy is lower than the cost of computation time when learning more RF trees. To avoid negative effect of the imbalanced classes, we combined the non-maize and grassland classes in one class. On the other hand, the RF model with five balanced classes and 500 trees resulted in an OA of 89.63% and K of 0.74. The individual class accuracy was 83.57% for maize, 92.75% for non-maize, 98.59% for tree, 85.15% for non-vegetation, and 92.65% for water. Overall, the balanced model performed better than the imbalanced

model for producing an accurate LULC map. In addition, analysing the RF variable importance by-product indicated that S1 layer had the highest mean decrease in accuracy as compared to other layers.

The results of the LULC classification were limited by cloud cover as such it was difficult to acquire a complete set of multi-temporal NDVI dataset. Figure 3 shows that correlation between NDVI temporal profiles is higher at the adjacent maize development phases in each season. For instance, between May and June which are maize tasselling and maturation development stages, respectively, the correlations between NDVI profiles were high (Figure 3). These correlations dropped towards September, which is the maize harvesting stage. Interestingly, the correlation between NDVI profiles between June 2015 and overlapped area at June 2014 is only 0.39 which is considered very low (Figure 3).

The performance metrics of the OCSVM as P-classifier model that were used to map the high severity MLN maize is presented in Table 1 and Figure 4. In the present study, the results of the P-classifier without manual model selection showed that the positive hold-out predictions (dark blue box) are located at the far right and separated from the negative hold-out predictions (light grey box) at the far-left side (Figure 4). Nevertheless, the confusion is high as some of the positive holdout predictions located at negative region. Additionally, there was no discriminative low-density region between these two classes. Our results demonstrated that a model based on the high puAuc did not show better performance comparing to the default model and leaded to high confusion rate. The grid (Figure 4(a)) shows that the puF dropped sharply at "Sigma" values smaller than 0.11 and greater than 1.4 and "nu" higher than 0.3. However, it is possible to find a finer grid (Figure 4(b)) around "Sigma" = 0.11 to achieve a better model. The diagnostic plot implies that the positive-labelled target class (high severity MLN) and the negative-labelled class (all other MLN severity levels) in both try (before and after manual interpretation and selection) can hardly be separated without high confusion rate.

With the test set (±test), an accuracy assessment for the binary classification results over the whole range of possible thresholds was performed (Table 2). Because of limited number of available training samples, it was not possible to provide bigger P training samples to cover wider spectral ranges. Low-density area in a histogram usually interprets as a good class separation. From the BSVM classification results, it was clear that high confusion rate existed between high severity MLN and healthy maize fields even after thresholding (Figure 5). It is important to highlight the fact that a clear low-density area does not exist between positive and

Cropping calendar		Short rainy season					Long rainy season						Short rainy season						Long rainy season			
		Planting Long rainy season harvest					Planting Short rainy season harvest						Planting Long rainy season harvest						Planting Short rainy season harvest			
Year		2013		2014															2015			
Month		N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
2013	N			0.37				0.57	0.56	0.49	0.50	0.50			0.50		0.29			0.43	0.41		0.51
	D	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2014	J							0.36	0.39	0.49	0.46	0.45			0.43		0.44			0.37	0.35		0.43
	F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	A	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	M								0.86	0.57	0.44	0.55			0.58		0.29			0.45	0.44		0.53
	J									0.72	0.45	0.54			0.67		0.20			0.42	0.39		0.51
	J										0.50	0.43			0.66		0.21			0.40	0.37		0.45
	A											0.68			0.49		0.40			0.36	0.36		0.54
	S														0.51		0.45			0.48	0.48		0.54
	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	D																0.19			0.38	0.36		0.54
2015	J	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	F																			0.21	0.26		0.50
	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	A	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	M																				0.93		0.43
	J																						0.44
	J																						
	A																						

Figure 3. Correlation between maize normalized difference vegetation index (NDVI) profiles (2013–2015) during the short and long rainy seasons at Bomet, Kenya. Numbers indicate the correlation between NDVI profiles. (-): No data were available.

Table 1. Manual model selection for one class support vector machine (OCSVM) classification of Maize Lethal Necrosis (MLN) severity, model parameters, and performance metrics.

Row	sigma	nu	tpr	puP	ppp	puAuc	puF	puF1
11	0.11	0.05	0.93	0.41	0.344	0.93	2.6	0.57
12	0.11	0.10	0.88	0.42	0.316	0.92	2.5	0.57

unlabelled region in the produced histogram. This demonstrates that training the model with a few numbers of training samples were not leaded to an optimal classification result.

The OA at Θ_0 and Θ_{opt} for classifying high severity MLN was 96%, K = 0.88 and 97%, K = 0.93, respectively. At Θ_{opt}, the UA increased 7% which was a result of lower commission or lower false-positive rate. Similarly, PA at positive test set remained unchanged which means the true positive rate was not reduced. Since it was not easy to determine an optimal threshold, visual inspection was performed too. Finally, Θ_{opt} was chosen because of its less false-positive rate (Mack et al. 2014). The result of the high severity MLN classification based on BSVM classifier is displayed in Figure 6.

The classification of the maize field at the long rainy season was challenging due to insufficient (only maize fields) ground truth samples. BSVM was chosen to classify maize fields on L8 imagery at long rainy season. It is important to note that a random sampling approach on the whole training dataset could be used to build unlabelled training samples. In this study, the manual U training sample selection was conducted to build up more representative U training samples. BSVM classification's histogram (Figure 7) showed high confusion between P and U classes and the Zu and Zp did not show a better separation among the classes. A very tiny break was detected at the Θ_{opt} (0.93) of diagnostic histogram as presented in Figure 7. The confusion matrices and diagnostic plot indicated that the large part of the Zu samples was located at low z-values and some (i.e. 26) of the unlabelled samples located at $Z \geq 0$. This indicates that unlabelled samples were located wrongly where the optimal decision (positive) should be. Practically, a high number of U samples at the P region can indicate the negative effect of imbalanced training samples, which is expected with OCC classifiers. Tax (2002) and Dreiseitl et al. (2010) discussed the outliers issue in detail which is out of the boundary of this work. This misclassification was reduced by choosing Θ_{opt} during manual interpretation and thresholding. Our study showed that 31% of the maize fields in Bomet were under continuous cropping system (Figure 8).

Next step, BSVM classifier was used to classify mono and intercropping maize system in the study area. Figure 9 presents the diagnostic plot out of a balanced P and U training samples. This resulted to an OA of 85% at Θ_0. However, the balanced training samples resulted in a high OA, but analyses of diagnostic plot indicated that 26% of pixels were misclassified at an optimal side for the classified pixels. Notwithstanding, the imbalanced training sample resulted in a lower density region between P and U classes. However, 33% of the unlabelled samples were misclassified. This indicates that imbalanced (Larger U) training samples reached a better separation but also more confusion.
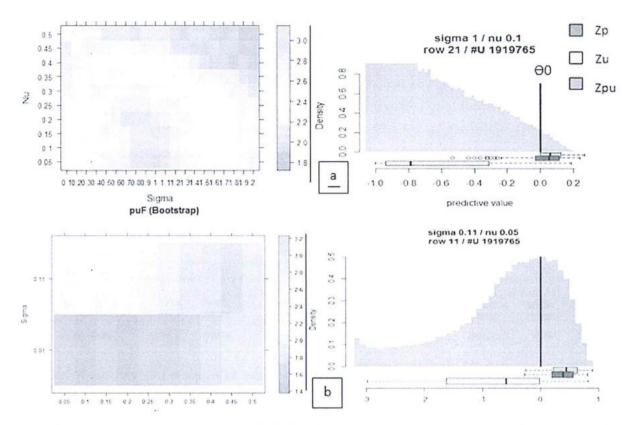
Figure 4. Default one class support vector machine (OCSVM) positive (P) classifier results for mapping Maize Lethal Necrosis (MLN) severity. (a) is the corresponding puF diagnostic plot, and (b) is the MLN severity classification after puF manual model selection. Zp: distribution of positive prediction, Zu: distribution of unlabelled predictions, Zpu: density histogram of the predicted image.

Table 2. Confusion matrices for high severity Maize Lethal Necrosis (MLN) classification using the biased support vectors machine (BSVM) classifier at Θ_0 and Θ_{opt} thresholds. The + Prediction row of the table corresponds to samples which predicted to be positive (+Pred./high severity MLN). Correctly predicted under +Test (high severity MLN test set) and called the true positives (TP). Inaccurately classified under -Test (low severity MLN test set) and were called the false positives (FP). Similarly, the second row contains the predicted negatives (-Pred./low severity MLN predicts) with true negatives and false negatives (FN). Low severity MLN correctly predicted under -Test (low severity MLN test set) were called the true negatives. Inaccurately classified under +Test (high severity MLN test set) were called the false negatives (FN).

Θ_0					Θ_{opt}				
	+Test	-Test	SUM	UA (%)		+Test	-Test	SUM	UA (%)
+ Pred.	(TP)218	(FP)40	258	84	+ Pred.	(TP)218	(FP)22	240	91
- Pred.	(FN)1	(TN)658	659	100	- Pred.	(FN)1	(TN)676	677	100
SUM	219	698	917		SUM	219	698	917	
PA (%)	100	94			PA (%)	100	97		
OA (%)	96				OA (%)	97			
AUC (*100)	99				AUC (*100)	99			
K (*100)	88				K (*100)	93			

Classification with imbalanced P and U training samples resulted with lower OA accuracy of 70% at Θ_0 (Figure 11). In addition, visualized raster showed that at Θ_{opt} a lot of salt and pepper effects were produced (Figures 10 and 12). After different threshold setting and visual inspection, the threshold 0.4 to 0.5 showed acceptable accuracy. In an optimal situation, larger P and U training samples can cover more complete spectral ranges and consequently the confusion between P and U should be reduced (Khan & Madden, 2014). Bigger training samples here have increased the computational cost. Consequently, the model with smaller but balanced taring samples was chosen to reduce the misclassifications.

The average-rainfall analysis showed that towards the eastern side of the study area, the precipitation decreased gradually. Whereas, 26% of the study area with relatively higher average rainfalls was under maize intercropping system (Figure 10). At the same period, in the region with lower rainfall, 45% of farmers performed maize intercropping system (Figure 12). Further, our results showed that 60% of high severity MLN occurred at region with lower rainfall (Makone, 2014). Figure 13 presents high severity MLN occurrences, intercropping system, and average rainfall at the western and eastern sides of the study area.

To date, several questions remain unanswered. There is a raising concern about the effectiveness of crop rotation to control MLN outbreak especially in those regions with
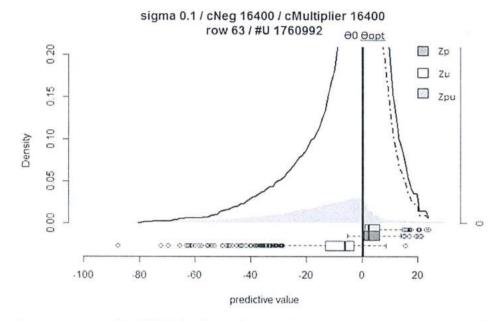
Figure 5. Biased support vectors machine (BSVM) classification diagnostic plot for mapping high severity Maize Lethal Necrosis (MLN). Zp: distribution of positive prediction, Zu: distribution of unlabelled predictions, Zpu: density histogram of the predicted image.
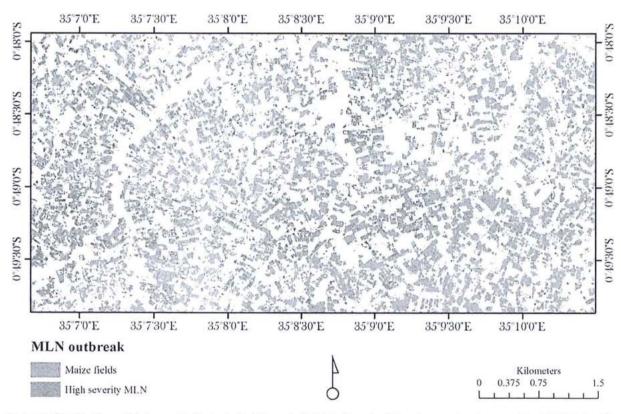

Figure 6. Classification of high severity Maize Lethal Necrosis (MLN) fields using biased support vectors machine (BSVM) classifier and RapidEye data (January 2015).

traditional small-size fields and absence of real cropping calendar. This is particularly important to be investigated that in which extends "long term" crop rotation can be effective to control MLN outbreak in a heterogeneous small-size farming system. Furthermore, distribution of mono and intercropping systems under different rainfall levels revealed that the intercropping system was more common at regions with lower rainfall. The results
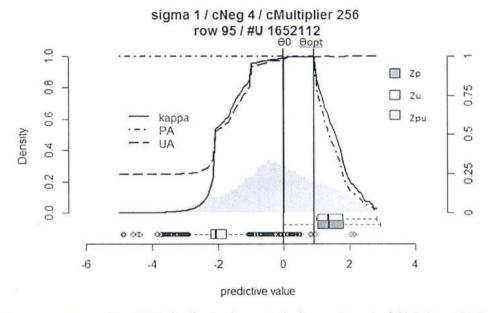
Figure 7. Biased support vectors machine (BSVM) classification diagnostic plot for mapping maize fields in August 2015 using Landsat 8 data. Zp: distribution of positive prediction, Zu: distribution of unlabelled predictions, Zpu: density histogram of the predicted image.
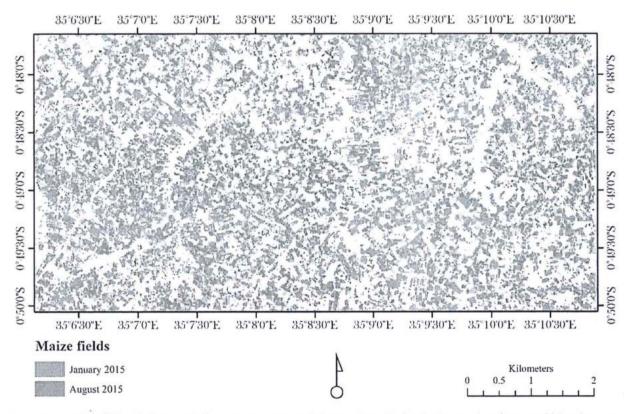
Figure 8. Overlay of classified maize fields in January 2015 and August 2015 obtained using random forest and biased support vectors (BSVM), respectively.
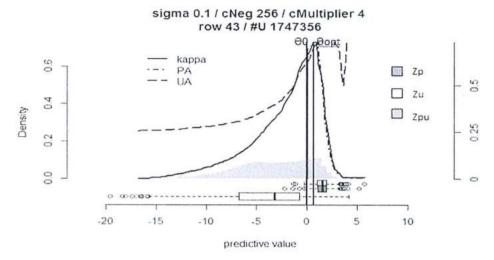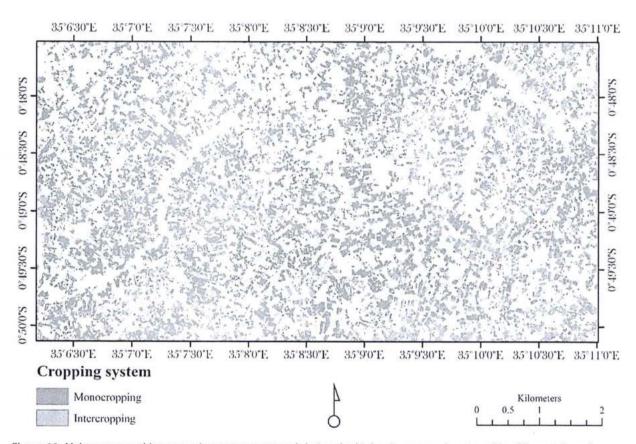
Figure 9. Biased support vectors machine (BSVM) classification diagnostic plot trained with balanced samples for mapping maize mono and intercropping systems. Zp: distribution of positive prediction, Zu: distribution of unlabelled predictions, Zpu: density histogram of the predicted image.

Figure 10. Maize mono and intercropping systems mapped during the high rainy season (western side of Bomet, Kenya).

confirmed that uncertainties in rainfall patterns have encouraged intercropping system in the low rainfall region.

5. Conclusions

This study utilized medium and high spatial resolutions optical (i.e. L8 and RE, respectively), and SAR (i.e. S1, SRTM DEM) datasets towards a better understanding of maize cropping system and high severity MLN occurrences in heterogeneous landscape in Bomet county, Kenya.

Using representative training samples and balanced classes in RF, a LULC map with OA of 89.63% was achieved. We have found a high correlation between maize fields' NDVI at the adjacent maize development phases such as tasselling and maturation in the same
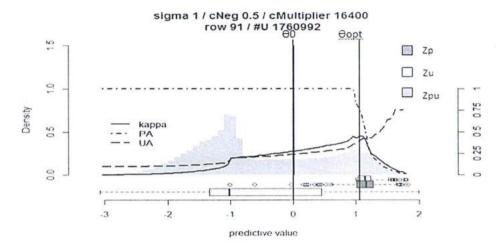
Figure 11. Biased support vectors machine (BSVM) classification diagnostic plot trained with imbalanced samples for mapping maize mono and intercropping systems.
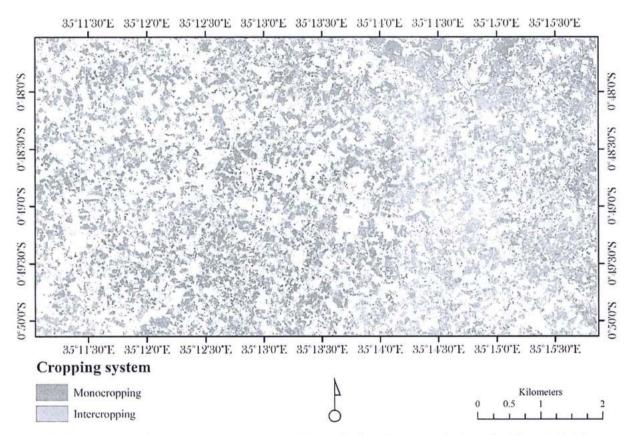

Figure 12. Maize mono- and intercropping systems mapped during the low rainy season (eastern side of Bomet, Kenya).

cropping season. The correlation between maize fields' NDVI in June 2015 and overlapped area at 2014 was only 0.39 which can imply the effect of MLN outbreak on maize crop in the region. Classification of maize fields during long rainy season using L8 imagery and BSVM classifier have been successfully performed. In contrast, RF classifier did not show any outstanding performance with only two classes (i.e. maize and non-maize). This indicates that in the presence of only one known class as training sample, OCC

classifiers performed better comparing to RF, which is known as a multi-class classifier.

Classifying high severity MLN and also maize cropping systems (mono and intercropping) using BSVM, performed successfully even the results showed a high confusion rate. Investigating the high severity MLN distribution under different rainfall levels indicated a relatively higher MLN-infected area under lower rainfalls. At the same time, more farmers tended to practice intercropping at lower rainfall levels.
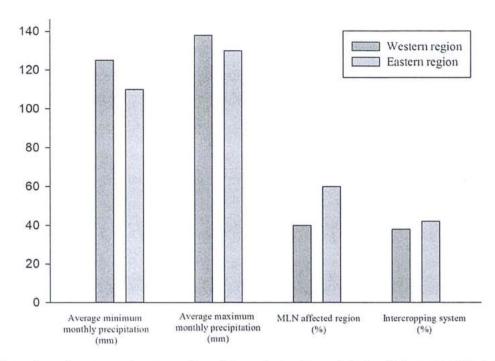
Figure 13. Comparison of western and eastern regions of the study area for precipitation, high severity Maize Lethal Necrosis (MLN), and maize intercropping distribution.

To have a better understanding of ecological variables' influence on MLN occurrences, further studies should be performed utilizing long term, constant, and accurate data collection methods. In other words, it is important to analyse MLN outbreak trends from the initial year of observation to a longer period to provide a better understanding of MLN occurrences and distribution. Further studies are certainly required to determine presence/absence, alternative hosts, vectors, seasonality of viruses like MCMV and SCMV, and other related ecological factors causing MLN specifically in East Africa. Overall, it will be important to investigate the role of climate change on MLN outbreak to get a better understanding of its effect on food security in Africa.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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