5TH INTERNATIONAL CONGRESS ON PLANTED FORESTS

Session 5: Planted forests facing global change risks

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KENYA FORESTRY RESEARCH INSTITUTE

Declining Tree Health in Exotic Forest Plantations: Exploring the Potential for Indigenous Tree Species for Sustainable Forest Plantation Development in Kenya

Njuguna Jane, Cherotich Sheillah, Okeyo Michael, Karani Susan, Muthama Angela and Machua Joseph and Mwangi Linus

ICPF 2023

Introduction

- Forest plantations development started in the Planted forests are to provide commercial goods and other ecosystem services.

- Continually face health challenges from diseases and pest occurrences due to their uniform genetic make-up.

- Management sometimes complicates tree health

Main Tree Plantation Species in Kenya

1. Pines,
2. Cypresses,
3. Eucalypts,
4. *Acacia mearnsii* (Dying) and;
5. *Grevillea robusta:* An agroforestry species *among others*
   - Introduced to East Africa between 1880s and 1910
   - Intensified till the 1980s.
   - Logging bans have interupted due to over harvesting
   - Forestry research started formally in 1934 arising from the emerging problems

Our Goal: Well Managed Productive Plantations

Grevillea robusta on Farms

Some Disease History in Forestry Development

- **Dothistroma blight** decimated *P. radiata* in the 1960´s.
- Attacked *P. patula* in Taita Hills in 1956 and in Nyeri first time early 1960s.
- **Cypress canker** caused by *Seridium* sp. on *Cupressus* maculata was detected in the 1960s.
  - *Cuppressus maculata discontinued in the 1970s*
- Led to the discontinuation of most cypresses.
- Currently the remaining *C. lusitanica* and other ornamentals are under attack from the resurgence of the disease
- Search for elite resistant germplasm is a must ongoing

Some Observations

- Unpredictable weather in the last 20 years,
- Increasing length of drought period
  - Negatively affecting the survival of exotic planted forests in the region.
- **Gradual increase in stem cankers and dieback symptoms since the 1990s in plantations and some farm forests**.
  - Caused by Botryosphaeriaceae & *Teratosphaeria* disease complexes
- In some case, mortalities occur especially in old trees.
- Disease symptoms seem to closely relate to variations in local weather conditions;
  - severe during hot and dry conditions

What is a Decline Disease?

- A decline disease has the following characteristics (Manion 1991):
  - Slow, progressive deterioration in health and vigor,
  - Primarily affects a mature cohort of trees
  - Decreased growth and increased twig and branch dieback
  - The etiology is complex and may involve important contributions from abiotic and biotic factors.

Decline Among the Cuppressaceae

The decline is not attribute to one fungal family only

Decline among the Pines

Nyeri, 2016

Transnzoia, 2016

Search for Alternatives: Focus on the Arid & Semi Arid lands (ASALs)

- ASALS offer the space for forestry expansion in Keny*a*
- *Pathology* to enhance resilience of indigenous tree species to climate change;

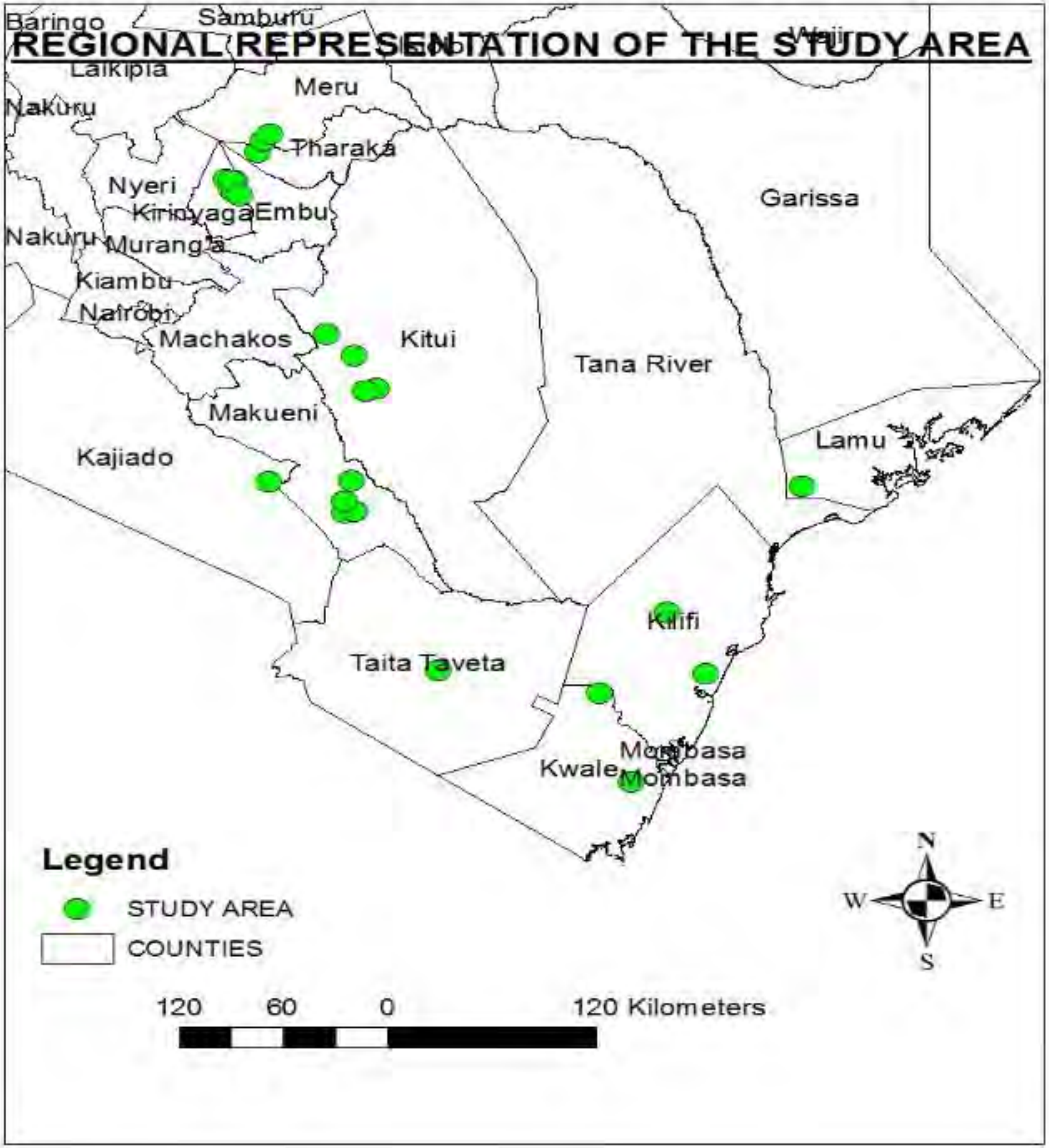
"To Select and promote disease resistant "indigenous tree species" for sustainable forestry practices and on-farm tree production in the ASALs of Kenya and Uganda".

Funded By the Swedish Research Council; 2016

  - A general survey undertaken
  - 3 Masters Thesis Completed
  - One PhD completed

- Screened twenty six (26) tree species for canker and dieback disease symptoms in Eastern and Coastal Kenya.

Screened 26 tree species in 8 Counties (ASALS to the Coast)



The 24 Tree Species Screened

1. *Acacia meleifera*
2. *A. polyacantha*
3. *A. Senegal*
4. *A. tortilis*
5. *A. xanthophloea*
6. *Adansonia digitata*
7. *Afzelia quanzensis*
8. *Azadirachta indica*
9. *Berchemia discolor*
10. *Carisa edulis*
11. *Dalbergia melanoxylon*
12. *Delonix elata*
13. *Maesopsis emini*
14. *Melia volkensii*
15. *Milicia exelsa*
16. *Moringa oleifera*
17. *Phoenix reclinata*
18. *Sclerocarya birea* (Amarulla)
19. *Senna antomaria*
20. *Syzygium* spp.
21. *Tamarindus indica*
22. *Tectona grandis*
23. *Terminalia brownii;*

Three (3) Selected Decline Case Studies

- **All studies followed standard pathological and molecular techniques**

Case Study 1

A canker and Dieback Disease Threatens the Growth of *Grevillea robusta* in Kenya

Jane Njuguna

1. Health Status of *Grevillea robusta*

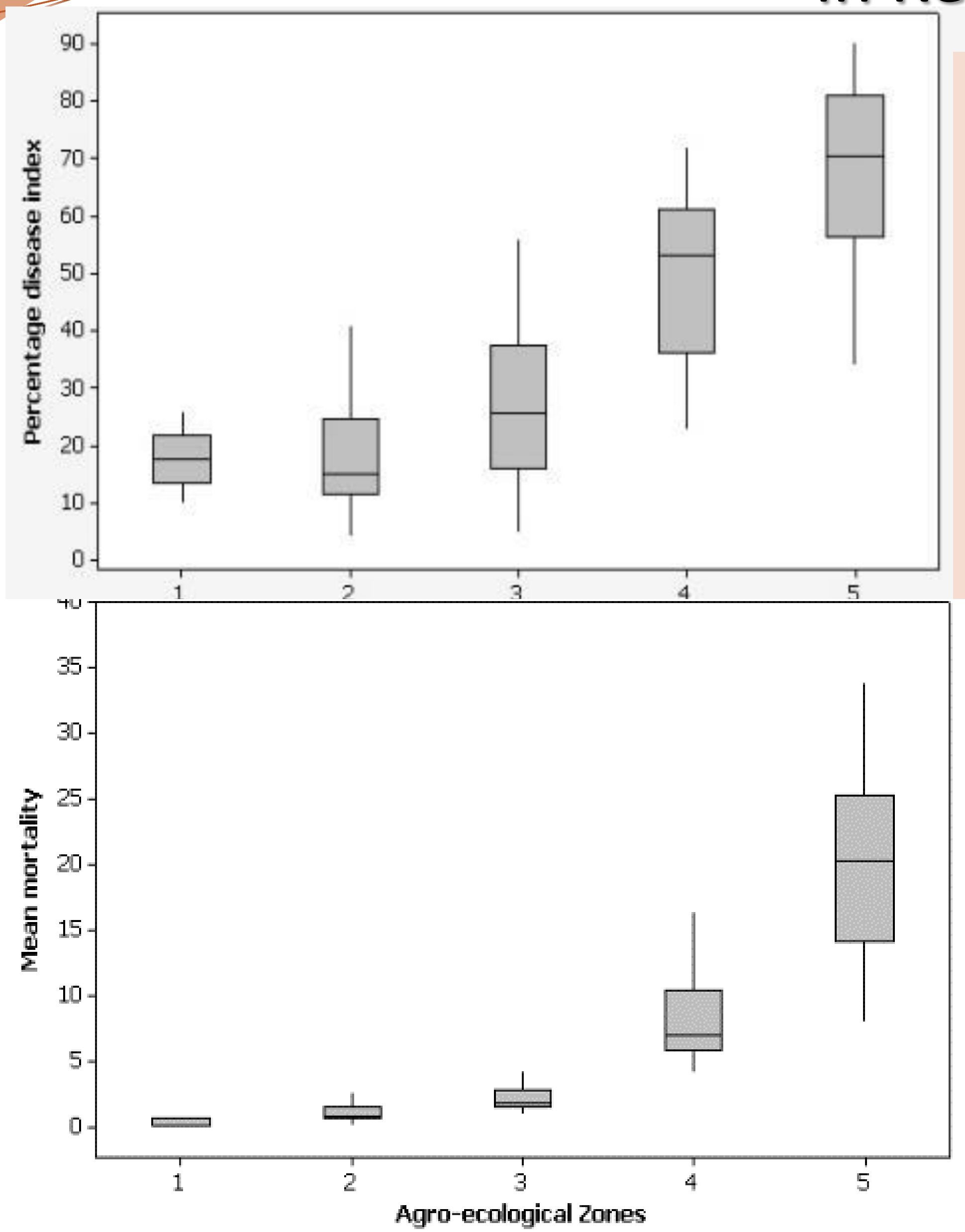
- Introduced as a shade and windbreak tree for tea & coffee plantations.
- ***Together with Eucalypts they form a near monoculture*** in the humid areas and extending to the ASALs and is now considered a "***commercial***" timber species
- **No serious disease reports until the 1990s.**

BUT

- **Stressful conditions beyond the optimal range seem to predispose it to the** canker and dieback disease caused by Botryosphaeriaceae disease complex
  - Fusicoccum group:
    - *Neofusicoccum parvum and Botryosphaeria* sp
  - Diplodia group:
    - *Lasiodiplodia theobromae and Diplodia seriata*

Resinous stem cankers and severe dieback on infected *G. robusta*

Disease Severity and distribution in 5 agro-ecological zones in Kenya



- Canker and dieback disease index (DI) increased from 18% in the humid zone to 67% in the semi-arid zones.
- Tree mortality also increased from 2% to 18%.
- Positively correlated with length of annual drought period in the zones
  - (p <0.001, Pearson corr. = 0.89).
- **Njuguna *et al* 2011. AJAR**

Pathogenicity Tests

- Under hot and dry conditions;
  - *G. robusta* was highly susceptible to the disease pathogens, High mortality of >90%.
  - A warming climate wont favour its growth
  - *Senna Siamea* and *Azadirachta indica* were moderately susceptible; Mortality <10%

- ***Melia volkensii* was the least susceptible** and **showed high incidences *of wound healing*** after 10 months of inoculation and low mortality (Njuguna 2011);
  - Mortality <0.1%

M. volkensii is a good candidate for forestry development in the ASALS); Njuguna 2011

Case Study 2

Canker and dieback Disease of Eucalyptus species in Kenya

Joseph Machua

2. Eucalyptus Canker and Dieback Disease

- No major disease threats until the early 1990s when the Botryosphaeria canker disease emerged.

- Currently attacking many Eucalyptus species in Kenya causing
  - Shoot and branch dieback,
  - Dry & resinous stem cankers giving the brownish to blackish appearance on stems.

- **Mild in cool areas, severe** in the marginal to hot areas and **death** is common.

- Some clones performed poorly or **failed** beyond the sub-humid areas.
- *E. camaldulensis* performs well in the marginal areas

Increasing common Occurrence on Eucalypts

Stem cankers and death of Mature Eucalypts in the Semi arid areas

Semi arid areas

Four Tree Species on the Same Dry Site

Melia volkensii and Terminalias *Eucalyptus sp* *Acacia* spp.

Pathogenicity Tests

- Pathogenicity tests from five (5) detailed studies; **Measuring Mean internal lesion development in the inoculated plants** revealed that;
- Twelve (12) species were tolerant to the canker and dieback pathogens.
- These included *Melia volkensii, Acacia xanthophloea, A. tortilis, Sclerocarya birea*, *Adansonia digitata, Croton megalocarpus*, *Vangueria rotundata, Berchemia discolor*, *Azadirachta indica, Tamarindus indica, Olea europaea* and *Calodendrum capense.*
- Lesion development was negligible
- No death was recorded on any species: disease tolerant
- ***High incidence of wound healing in the tree species***
- Can be tested for plantation development in the arid and semi-arid areas which cover 80% of Kenya

Case Study 3

Canker and Dieback: A Threat to Domestication of *Adansonia digitata* and *Sclerocarya birrea* in Agroforestry systems in Eastern Kenya

Sheilah Cherotich

Example of Internal lesion development

Fig: *Observed symptoms after inoculations*

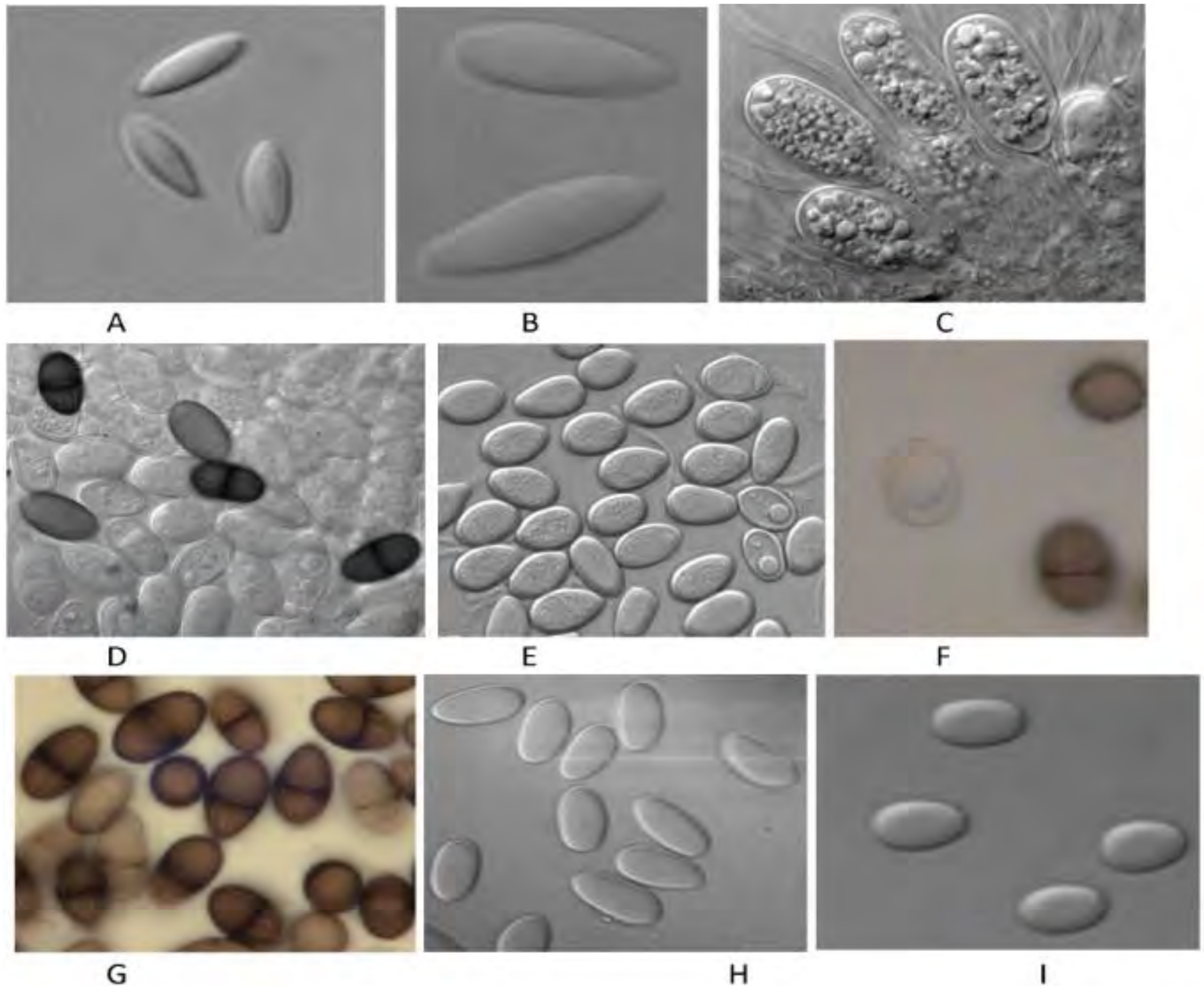
Selected tree species used in inoculation were;
Adansonia digitata,
Sclerocarya birrea,
***Calodendrum capense** and*
Acacia xanthophloea

Fungai isolates inoculated were; Lasiodiplodia pseudotheobromae, L. theobromae and N. parvum

Pathogenicity results:

- Visible symptoms observed were lesions with resin, dieback and **wound healing**
- All species developed lesions after a comparatively log time > 20 days
- No mortality was recorded

The tree species are able to tolerate the canker and dieback disease



Conidia characteristics of (A) *Neofusicoccum parvum*, (B) *Botryosphaeria* sp., (C-D) conidiogenous cells and young and mature conidia of *Lasiodiplodia theobromae*, (E) Young conidia of *L. parva*, (F) and (G) young conidial and maturing conidia of *L. pseudotheobromae*, (H) *Diplodia seriata*, (I) *Diplodia* sp.

Facts about the Canker and dieback Pathogens: The Botryosphaeriaceae

- Endophytes: part of normal flora of healthy plants
- Become opportunistic pathogens when the hosts are stressed by extremes of any factor that include the biotic and abiotic environment eg. water, temperatures, poor management etc.
- Plurivorous on a wide range of hosts (woody & herbaceous).
- **Grow vigorously under warm conditions**
- Indigenous tree species seem more tolerant the dieback disease

Conclusions

1. The species tested were all susceptible to the canker and dieback disease **But at varying levels in the ASALs**

2. The **12 species tested were tolerant to the** fungal pathogens indicating a possible co-evolution
    - *Melia volkensii, V. rotundata, B. discolor, O. europaea, C. megalocarpus, A. digitata, S. birrea,, C. capense, A. xanthophloea, A. indica, T. indica, S. siamea, E. camaldulemsis*

3. Shown remarkable capability to survive despite the infections with **high incidences of wound healing**

4. **The *Eucalypts, Cypresses* and *Grevillea robusta are progressively becoming*** susceptible and poorly adapted to the drylands

5. **Offers hope to the ambitious programme of growing 15Billion trees**

6. Breeding for improved qualities should be intensified and possibly isolate the drought and disease resistance genes….

Supporting Publications

1. Gitehi G., Kamondo B.M., **Njuguna J. W.,** Mwangi S., Kipkoech N., and Ingutia C. **(2023).** Rooting African Sandalwood stem cuttings using low-cost technology employed in the commercial propagation of *Camellia sinensis* in Kenya. Journal of Horticulture and Forestry: Vol. 15 (1), pp. 1-11.
2. Susan, K., **Njuguna J.,** Steven, R., Alice, M., Joseph, M., & Phoebe, M. **(2022)**. Molecular and morphological identification of fungi causing canker and dieback diseases on *Vangueria infausta* (Burch) subsp. *rotundata* (Robyns) and *Berchemia discolor* (Klotzsch) Hemsl in lower Eastern Kenya. *African Journal of Biotechnology*, *21*(1), 6-15.
3. Okeyo, M. M., Obwoyere, G. O., Makanji, D. L., **Njuguna, J. W**., & Atieno, J. **(2020)**. Promotion of *Terminalia brownii* in reforestation by development of appropriate dormancy breaking and germination methods in drylands; Kenya. *Global Ecology and Conservation*, *23*, e01148.
4. Sheillah Cherotich, Japhet Muthamia, **Njuguna J W.,** Alice Muchugi, Daniel Otaye, Ignazio Graziosi, Zakayo Kinyanjui (**2020**). Fungal Microflora Biodiversity of Healthy and Diseased *Adansonia digitata* and *Sclerocarya birrea* Trees in Kenya. *Topola/Poplar* 205, 5-13
5. Cherotich Sheillah, **Njuguna Jane**, Muchugi Alice, Muthamia Japhet, Otaye Daniel, Graziosi Ignazio and Kinyanjui Zakayo (**2019**). Botryosphaeriaceae associated with baobab (*Adansonia digitata* L.) and marula (*Sclerocarya birrea* A. Rich.) in agroforestry systems in Kenya. African Journal of Plant Science, Vol. 14(10), pp. 411-419
6. Okeyo, M. M., Obwoyere, G. O., Makanji, D. L., **Njuguna, J. W.,** & Omond, J. A. **(2019)**. Fungal diseases attacking floral phenology of *Terminalia brownii* in Drylands, Kenya. *Topola*, (203), 5-11.
7. Okeyo, M. M., Obwoyere, G. O., Makanji, D. L., **Njuguna, J. W**., & Gathogo, M. W. (**2019**). Insects Associated with *Terminalia brownii* growing in Kitui, Baringo and Homa Bay Counties, Kenya: Implications on Tree Species Domestication. *Topola*, (204), 5-15.
8. Muthama, Angela M., **Jane W. Njuguna**, and Francis K. Sang (**2017).** "Botryosphaeriaceae Fungal Species as Potential Pathogens of Meliaceae in the Arid and Semi-Arid Lands of Kenya. *Indian Forester* 143.9 (2017): 890-893.
9. Machua J., L. Jimu, **J. Njuguna**, M. J. Wingfield, E. Mwenje and J. Roux (**2016**). First report of *Teratosphaeria gauchensis* causing stem canker of Eucalyptus in Kenya. *For. Path.*doi: 10.1111/efp.12264.
10. **Njuguna J. W. (2011**). Stem Canker and dieback Disease on *Grevillea robusta* Cunn ex R. Br.: Distribution, Causes, and Implications in Agroforestry Systems in Kenya, PhD Thesis, Swedish University of Agricultural Sciences (SLU), Sweden.
11. **Njuguna J. W.,** Barklund, P., Ihrmark, K., and Stenlid, J. (**2011**). A canker and dieback disease is threatening the cultivation of *Grevillea robusta* on small-scale farms in Kenya. *African Journal of Agricultural Research* Vol. 6(3), pp. 748-756.

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- The Great Pathology Team

Great Pathology Team


Thank You!

5TH INTERNATIONAL CONGRESS ON PLANTED FORESTS

Drought-adaptive mechanisms in *Eucalyptus grandis* plantations:

key findings from 10 years of intensive monitoring in a throughfall exclusion experiment

Laclau J-P, Gonçalves JLM, Bouillet J-P, Christina M, le Maire G, Nouvellon Y

Introduction

- *Eucalyptus*: the most planted broadleaf genus in tropical regions (> 20 million ha worldwide)

- MAI of 40-50 m^3 ha^{-1} yr^{-1} in Brazilian plantations

- High productions of *Eucalyptus* plantations are highly dependent on substantial water and nutrient supply

- Tree mortality can occur on large areas during severe droughts

Objective

Our study aimed to **gain insight into** the **interaction between nutrition and adjustment to water deficit** in *E. grandis* plantations

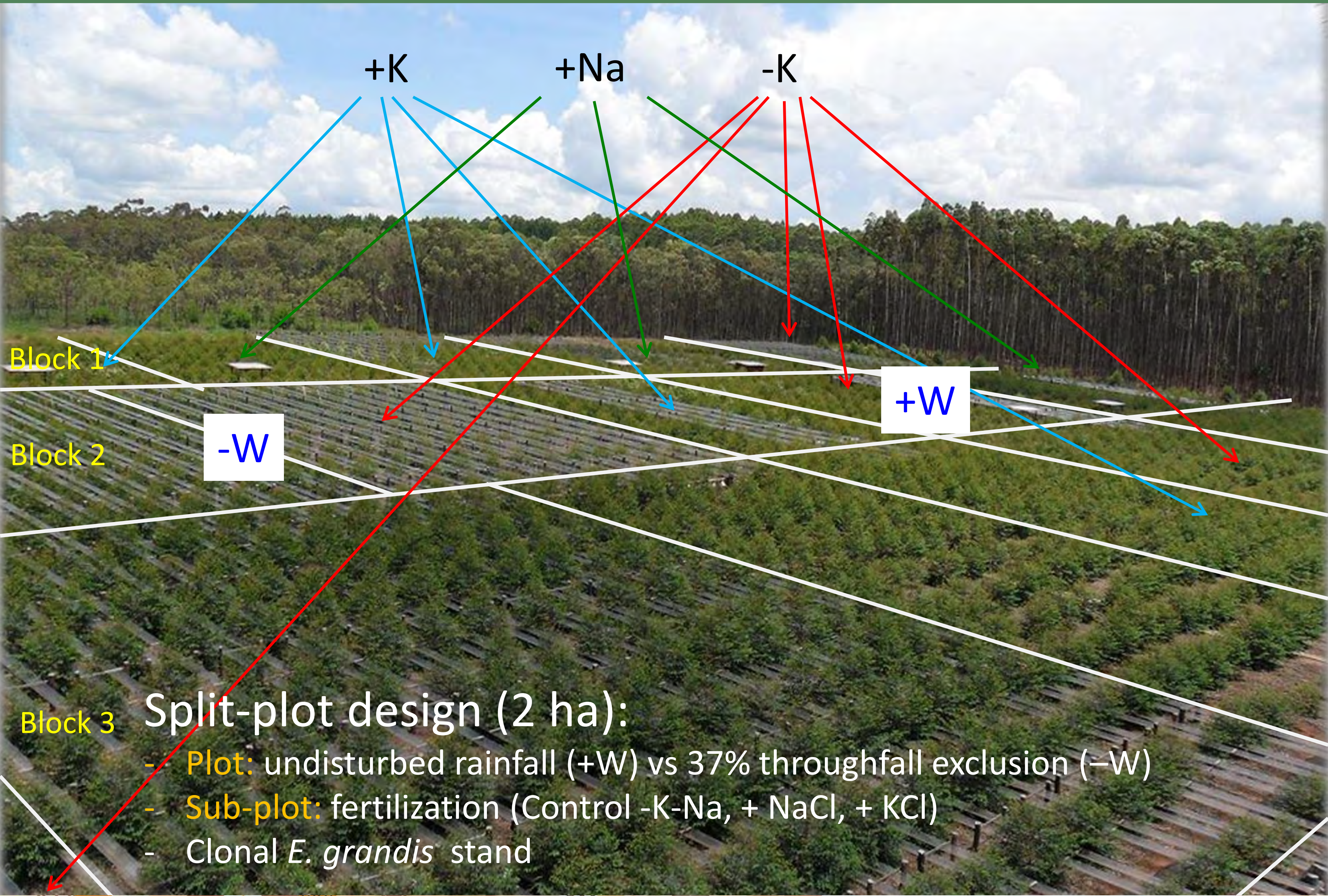
We focused on K and Na:

- KCl is the fertilizer the most applied in Brazil;
- A positive response of *E. grandis* trees to NaCl addition has been found in K-deficient soils

MATERIAL AND METHODS

- Study carried out **over an entire rotation of 6 years + coppice**
- Annual rainfall: **1400 mm**
- Mean temperature: **20°C**
- **Dry season** from June to September

Material and methods



Split-plot design (2 ha):

- Plot: undisturbed rainfall (+W) vs 37% throughfall exclusion (–W)
- Sub-plot: fertilization (Control -K-Na, + NaCl, + KCl)
- Clonal *E. grandis* stand

Material and methods

37% throughfall exclusion using plastic sheets

Litterfall

Trenches between plots

TDR probes down to a depth of 17 m

18 schaffolds

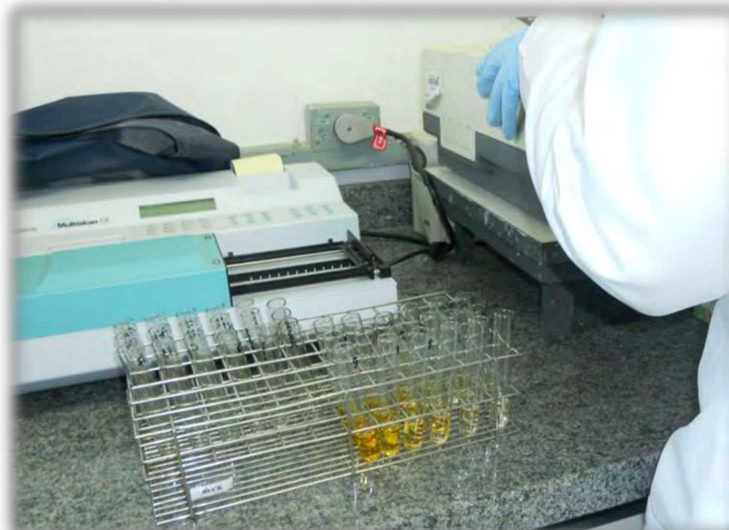
Material and methods

Sap flow measurements

Phloem sap sampling

Leaf gas exchanges
and leaf water relations

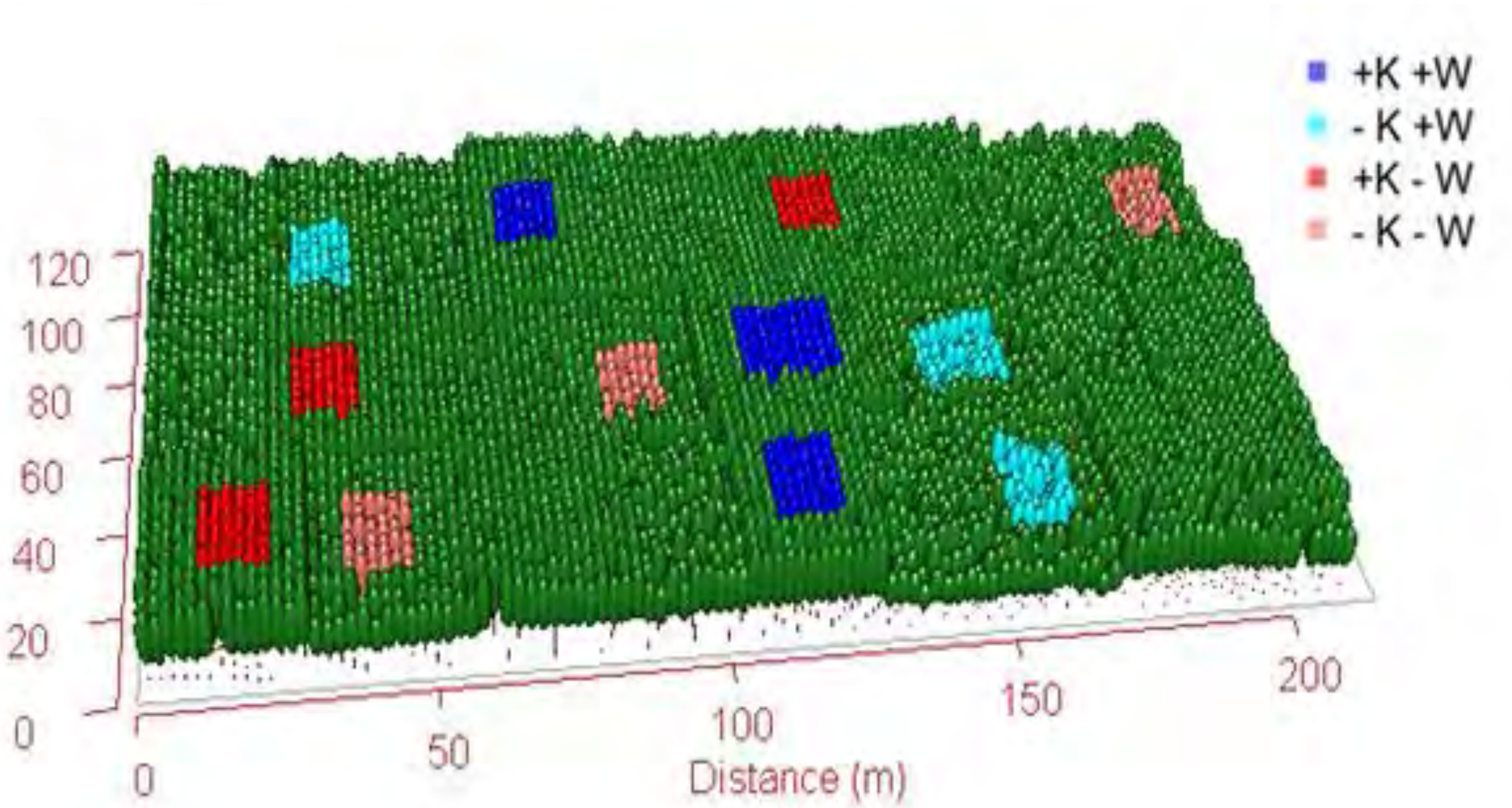
Leaf tagging and measurements



Sugar, starch and nutrient concentations

Material and methods

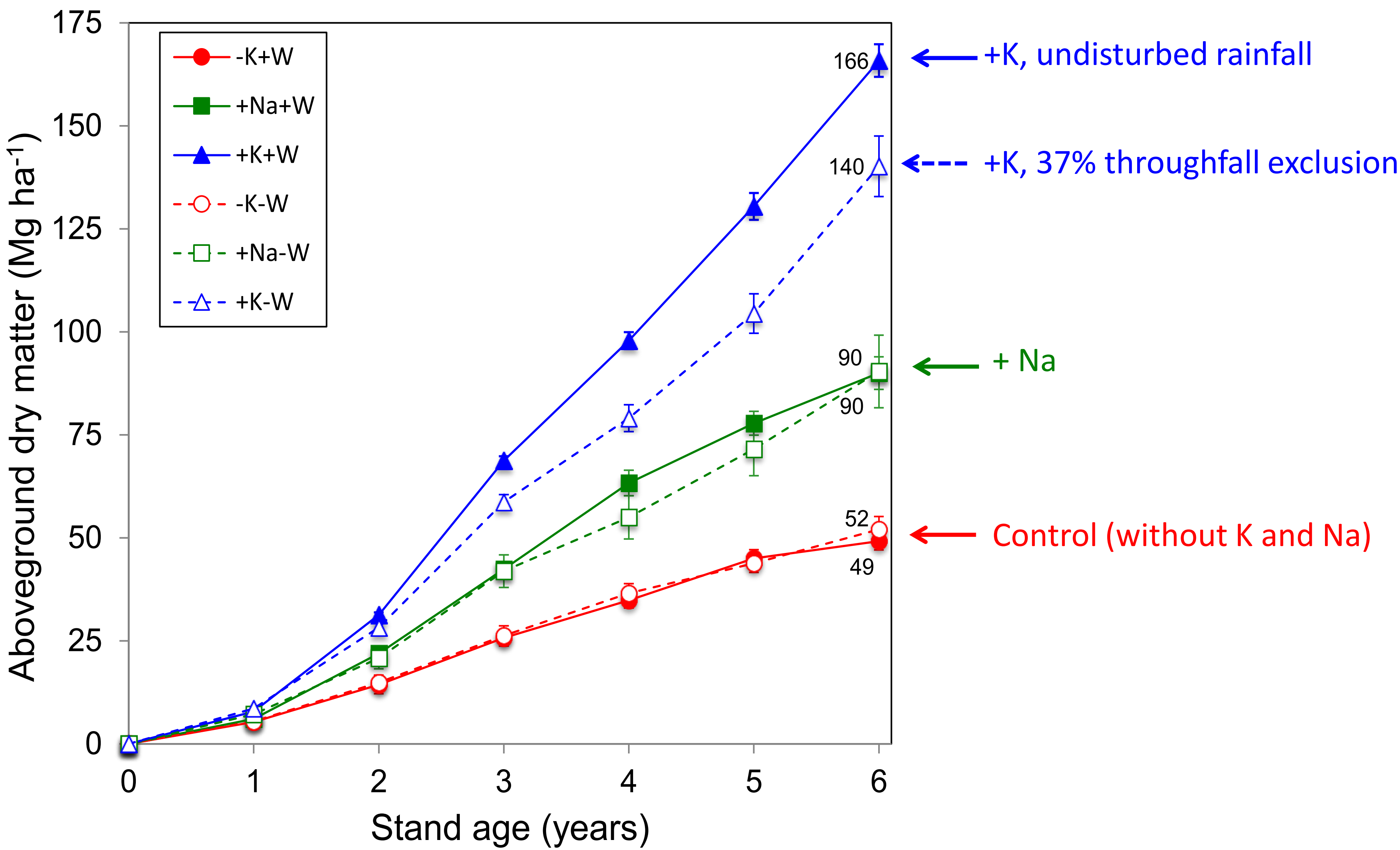
Interactive effects of K deficiency and water deficit on GPP and LUE



MAESPA model (validation from gap fraction and sapflow measurements)

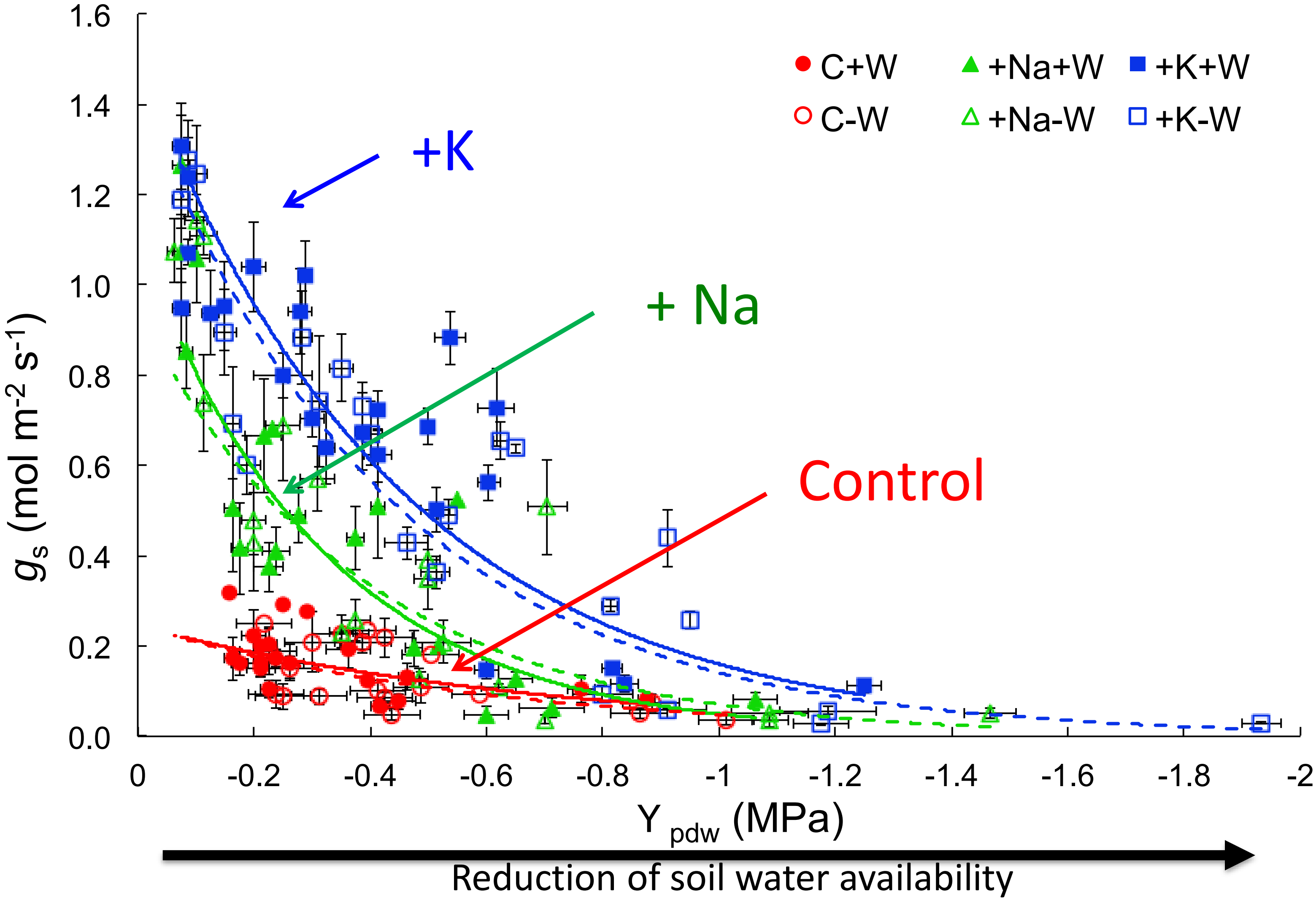
SOME RESULTS

Harvested biomass x2 with Na addition and x3 with K addition



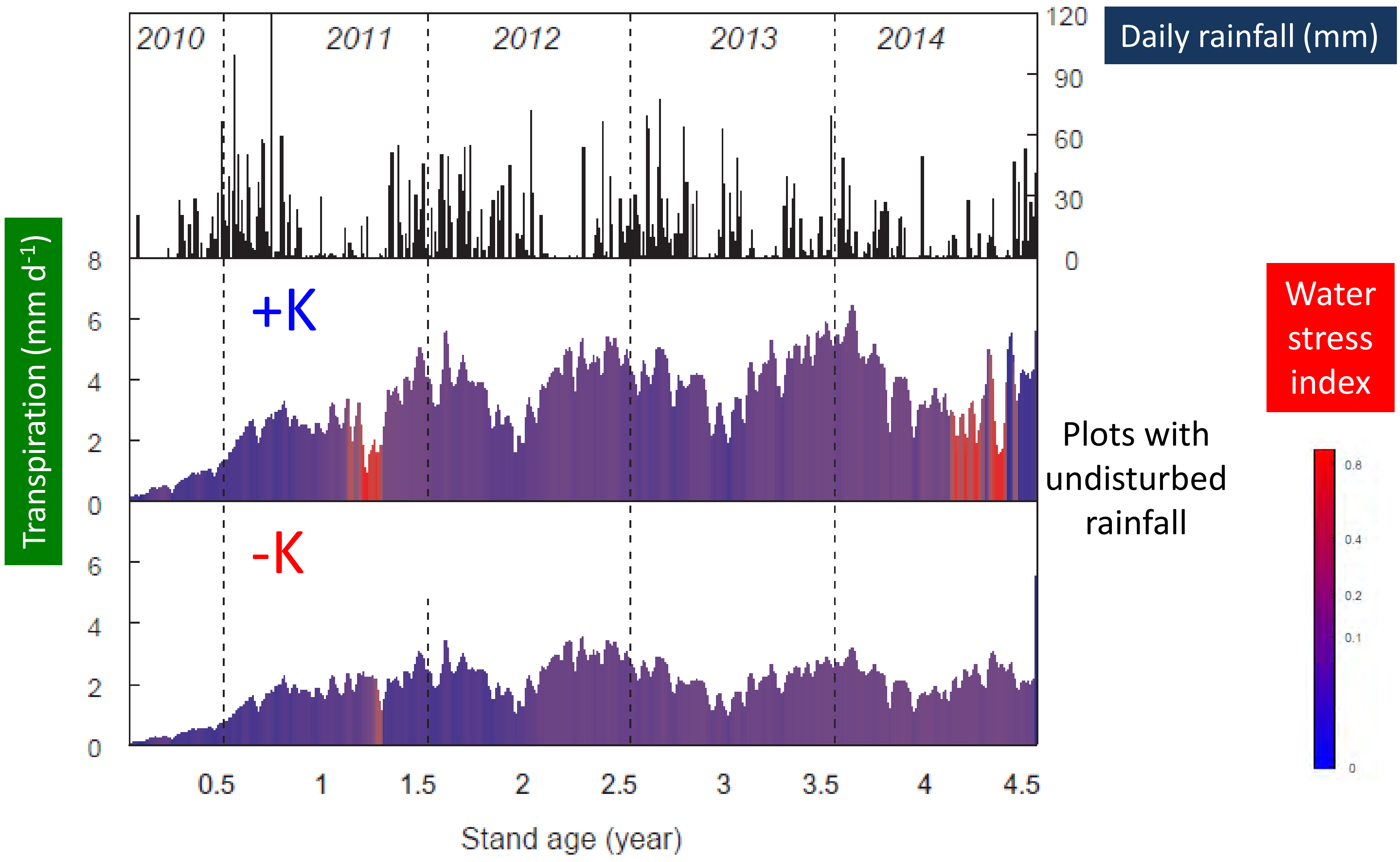
A depressive effect of throughfall exclusion: only when K fertilizer is applied

K and Na supply improve the regulation of gas exchange in the leaves



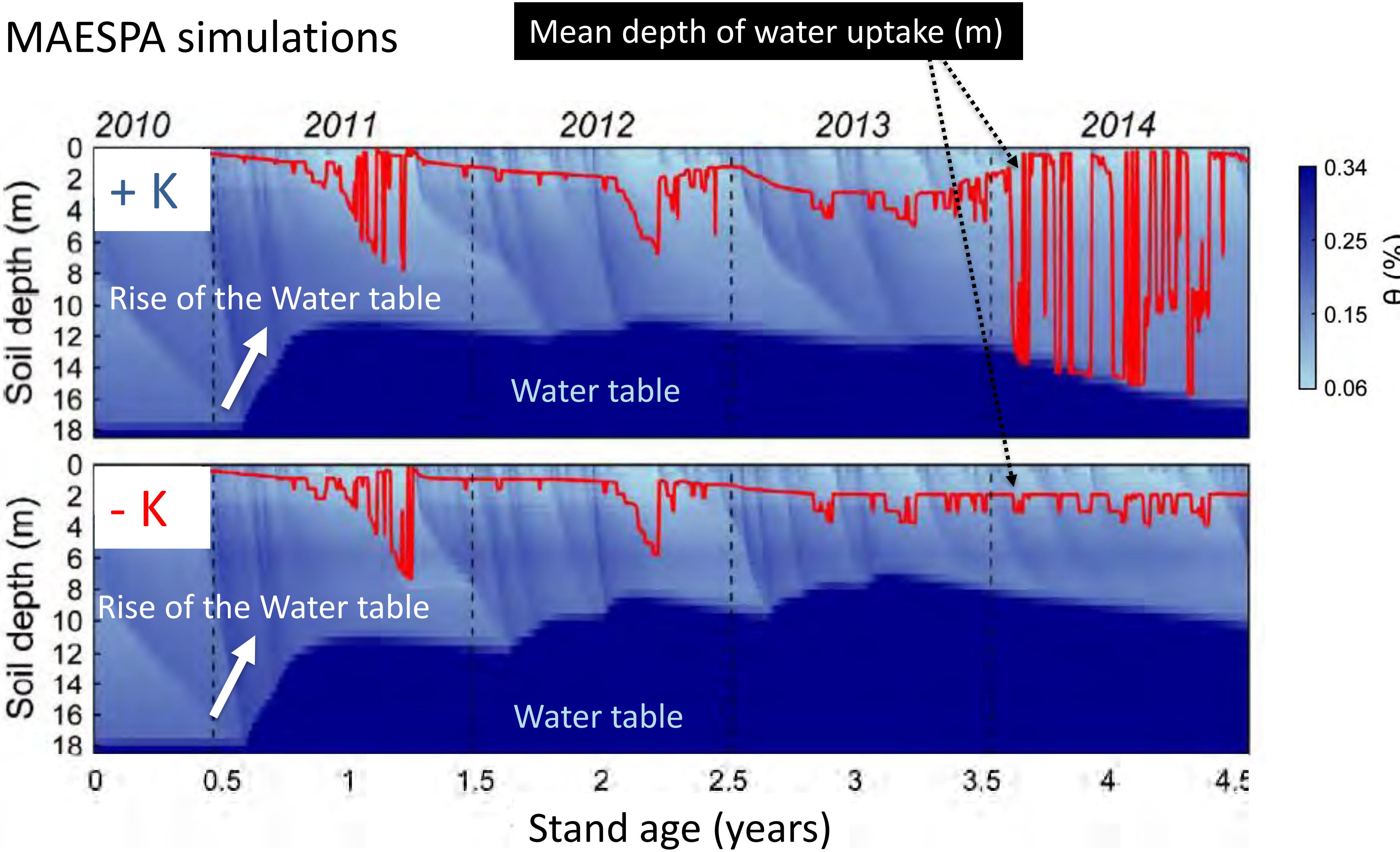
The stomatal response to changes in water availability was much higher in fertilized trees than in K-deficient trees

Much higher water demand of K-fertilized trees



K fertilization increases the depth of water uptake

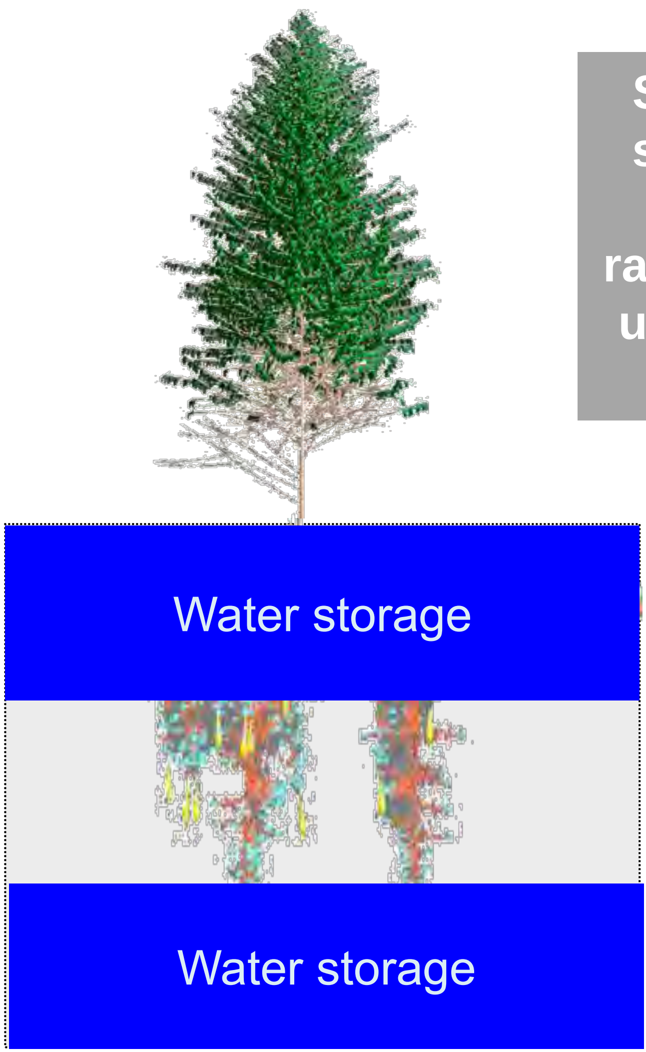
MAESPA simulations



K fertilization reduces the storage of water in very deep soil layers

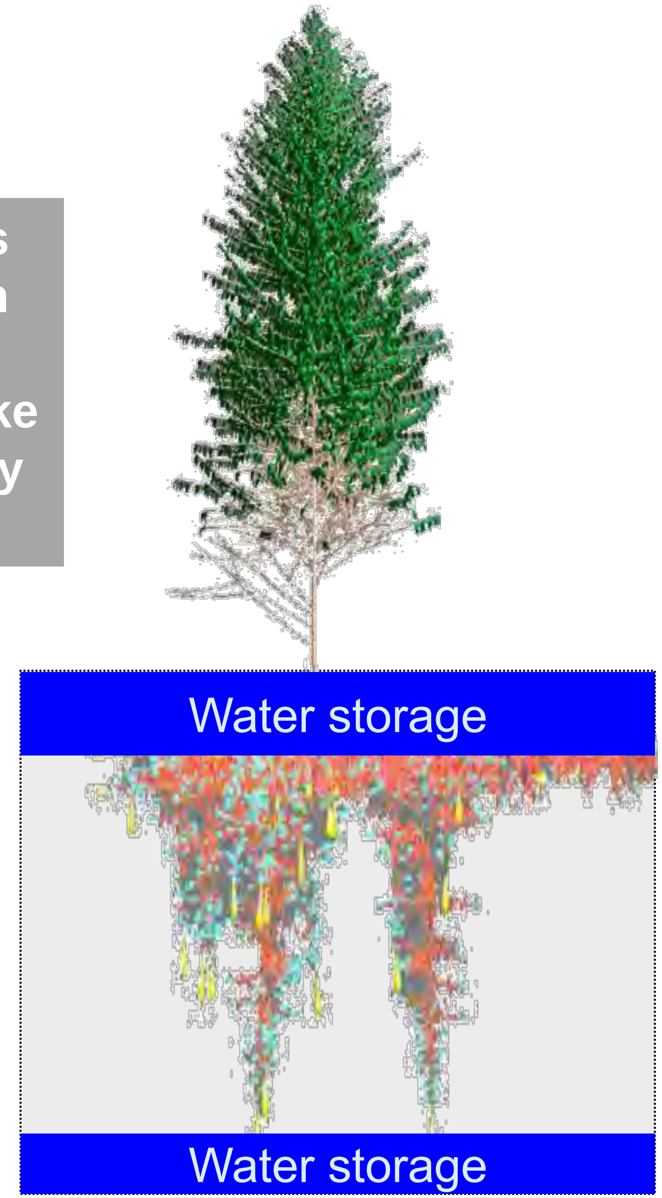
The recharge of soil layers is dependent on fertilization regimes

Nutrient deficient trees



Slow-growing trees store more water in the soil during the rainy season and take up less water in very deep soil layers

Fertilized trees



CONCLUSION

- **Strong interaction between K and water supply:** K fertilization increased tree sensitivity to drought ;

- **Fertilization must be revisited in a context of climate change**:

  - even though K fertilization improves stomatal regulation, high tree water demand can lead to higher **risks of hydraulic failure** during severe droughts;

  - **soil depth** is an important variable to consider in tropical forest plantations because very deep water storage can account for tree growth during dry periods.


Thank you

Pest risk survey of *Cupressus lusitanica* Mill. in Rift Valley region of Kenya

Angela Muthama
Researcher, Forest Pathology
Kenya Forestry Research Institute

5TH INTERNATIONAL CONGRESS ON PLANTED FORESTS

CIFOR-ICRAF CAMPUS
NAIROBI, KENYA

Presented on 9th November 2023

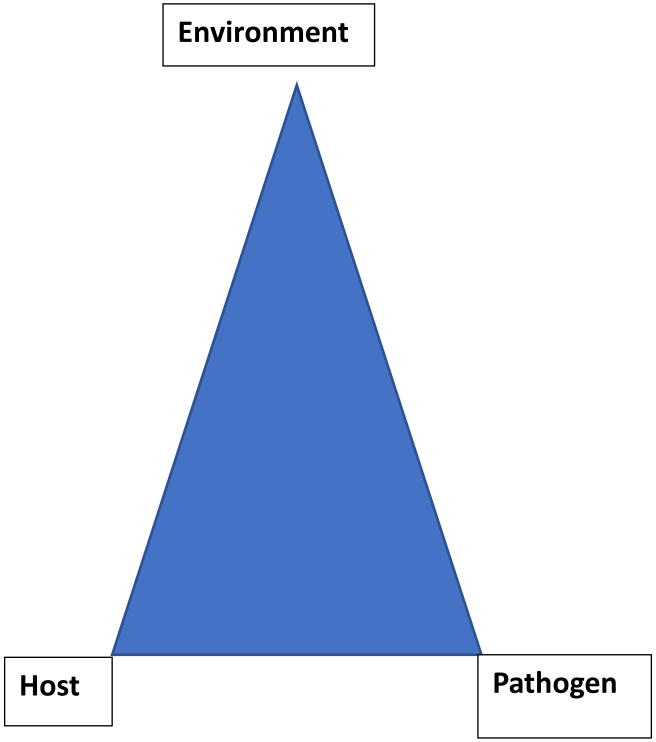
Presentation Outline

- Introduction
- Research Questions
- Methodology
- Results
- Discussion
- Next Steps

Introduction

- Forestry in Kenya began in the early 1880s as a science of managing available forest resources to provide timber and fuelwood for industry, construction and infrastructure development
- Exotic tree species were introduced including Cypress, Pines and Eucalyptus in large plantations
- In 1970s *Cupressus macrocarpa* was attacked by cypress canker disease leading to widespread infections that subsequently led to replacement of the species with *Cupressus lusitanica*
- In 1980s *Pinus radiata* was attacked by Dothistroma pine needle blight later being replaced with *Pinus patula* a less susceptible species
- Cypress requires deep fertile soils and does well in moist climate between altitudes of 1000-4000 m.a.s.l with annual rainfall of 800-1500mm, annual temp. 12-30 degrees celsius
- Main uses are sawn timber, pulp, as a wind break and fence

Why Study Tree Diseases



Tree Diseases can cause:
Death of shoots
Root rots
Leaf blights
Leaf spots and shot holes
Necrosis on leaves
Oozing on stems
Death of the entire tree
Species wipeout

Disease Triangle: Requirements for a plant disease to occur influenced by human activities

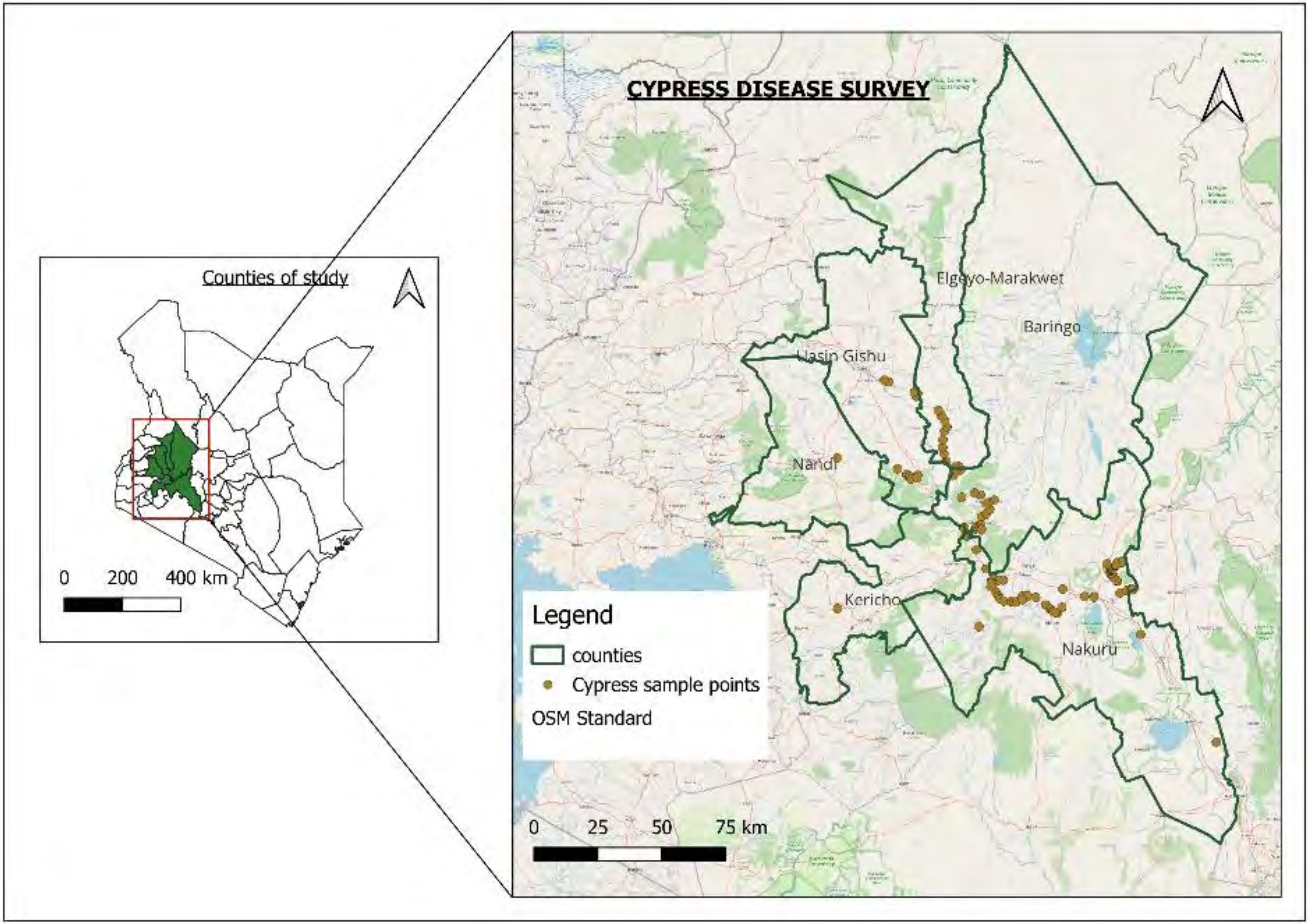
Research Questions

- a) What conditions favor disease infection of *Cupressus lusitanica* in the Rift Valley ecoregion of Kenya?
- b) Can the existing data provide patterns of disease outbreaks on *Cupressus lusitanica* in Kenya?
- c) How can machine learning help pathologists in decision making and management of tree diseases

Methodology-Field surveys

- Plantations of *Cupressus lusitanica* in gazette forests within Rift Valley ecoregion were surveyed and assessed for disease symptoms, the disease incidence and severity
- **Disease Incidence:** Percentage of diseased plants in a sample or population
- **Disease Severity:** the percentage of relevant host plant tissue that is covered by a symptom or lesion or damaged by the disease

Samples of symptomatic tissues were collected for laboratory analysis



Counties of study
0
200
400 km
CYPRESS DISEASE SURVEY
Elgeyo-Marakwet
Baringo
Uasin Gishu
Nandi
Kericho
Nakuru
Legend
counties
Cypress sample points
OSM Standard
0
25
50
75 km

Methodology- Laboratory isolations

- The cut pieces were surface sterilized by rinsing for one minute using 33% hydrogen peroxide and rinsed 3 times using sterile distilled water.
- The pieces were then blotted dry on sterile filter papers in the laminar flow before being aseptically placed in Petri dishes containing 2% Malt Extract Agar amended with Streptomycin.
- The petri dishes were then placed in controlled culture chambers with 12h alternating light and dark cycles
- Fungal growth was monitored daily and the emerging fungi were transferred on to culture media to obtain pure cultures of the fungi.
- Once pure cultures were obtained their morphological identification was done to get preliminary results on causal agent

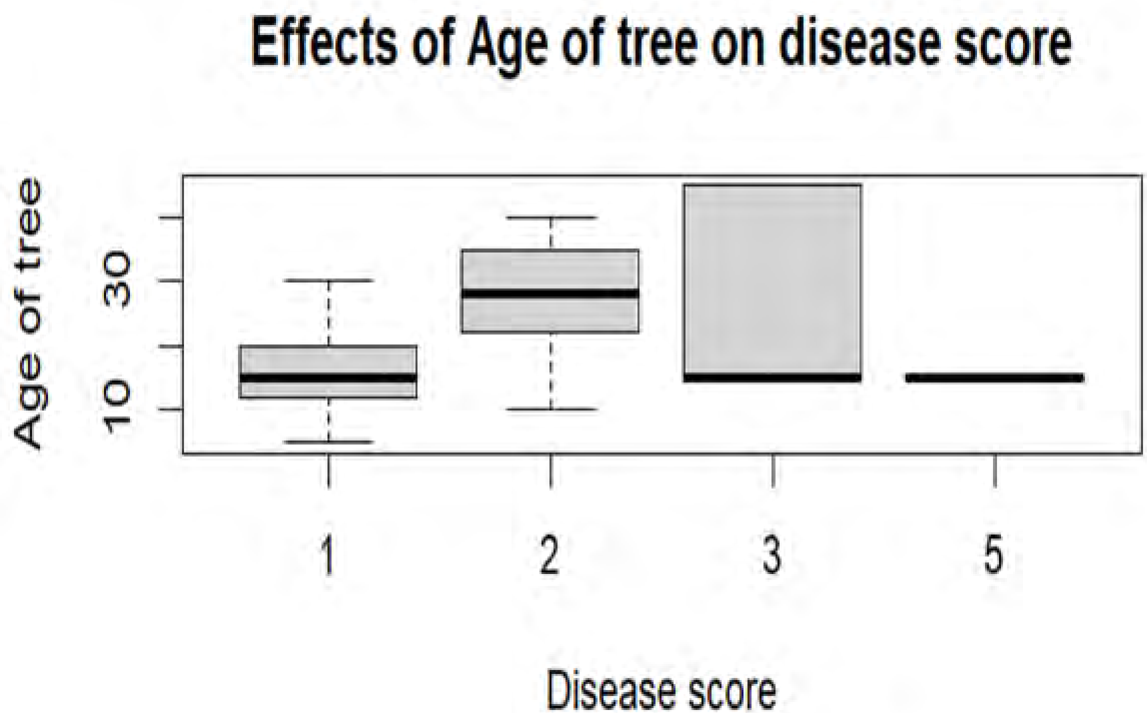
Results

- 67 plantations were assessed in the target area
- **Disease symptoms recorded were:**
- Branch dieback
- Cankers
- Tree mortality
- **Predisposing factors recorded on site were:**
- Injury by animals causing wounds on young shoots
- Poor pruning technique
- Poor or delayed thinning and pruning of stands causing low vigor

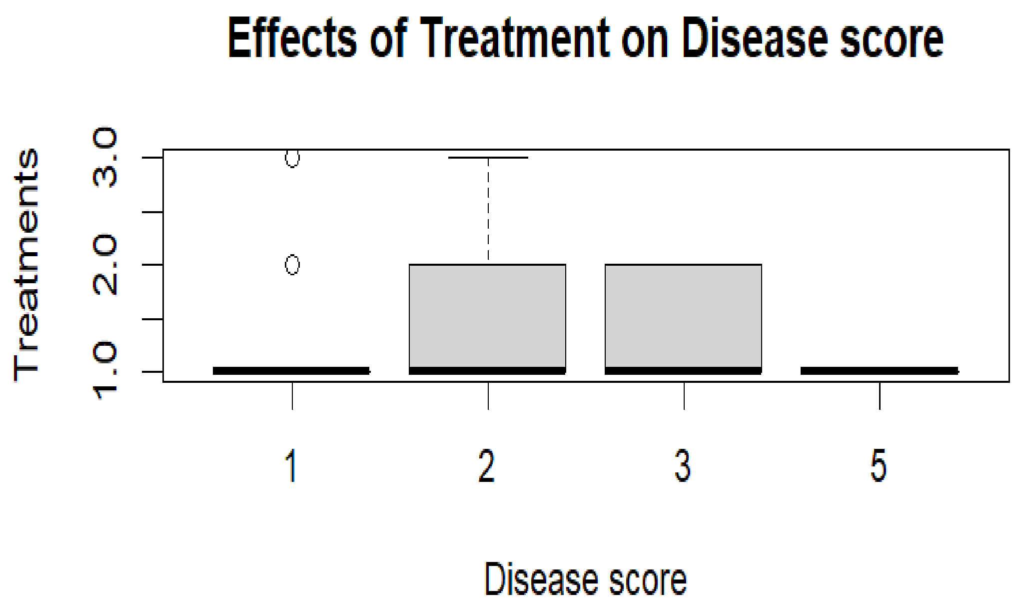


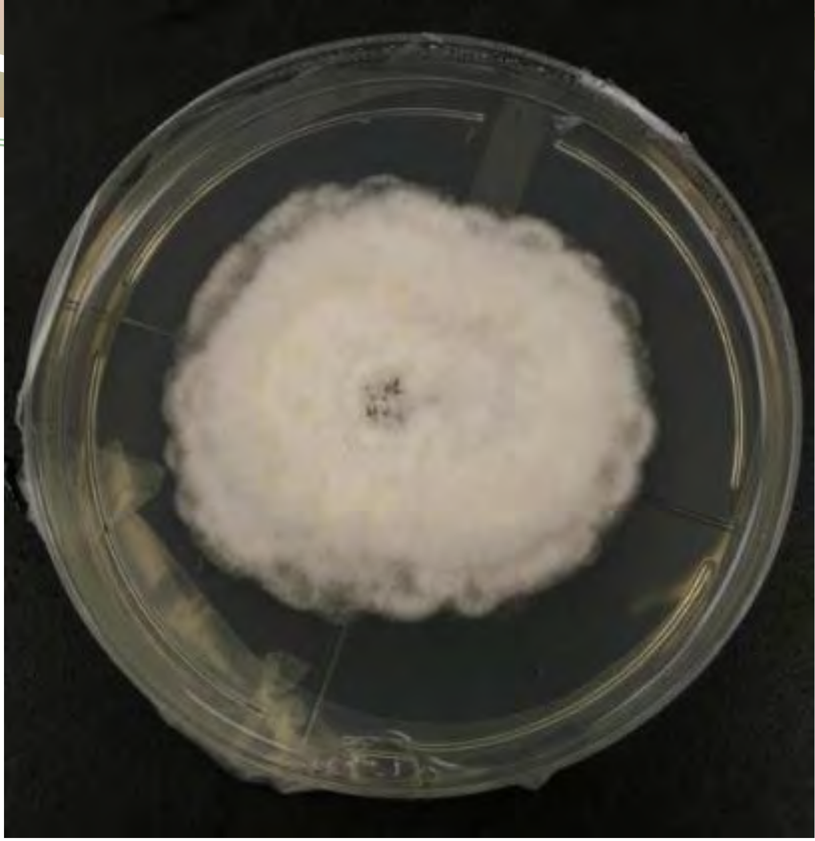


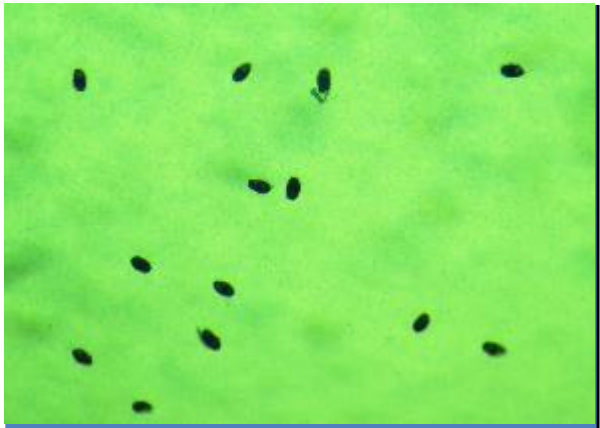


Effects of Age of tree on disease score
Age of tree
10
30
1
2
3
5
Disease score

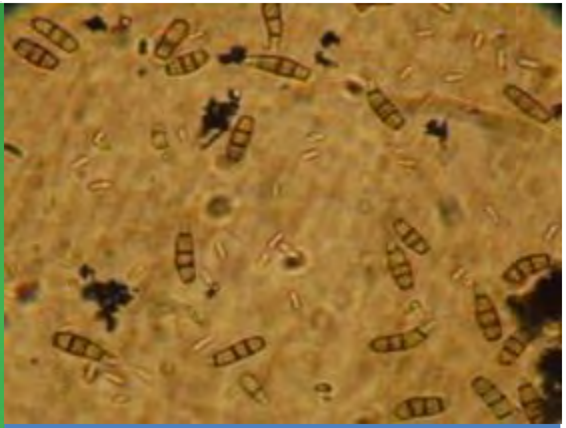

Effects of Treatment on Disease score
Treatments
1.0
2.0
3.0
1
2
3
5
Disease score





Botryosphaeriaceae sp.

Pestalotia sp.



Seiridium sp.

Discussion

- Delayed management operations had the biggest impact on the health of the stands assessed
- Poor species site matching was a challenge in private farms and woodlots
- With proper management disease infection and spread can be controlled by upto 90%
- Cypress technical orders for sawn timber:

Year	Thinning	No.of stems left
By Year 6	712	888
5 years after 1st thinning	355	533
10 years after 1st thinning	178	355
15 years after 1st thinning	99	256

Next steps

- DNA level identification of the fungi isolated from the study
- Complete algorithm development for predictive analysis of disease infection
- Develop maps for high risk areas
- Submit data in an open source data repository
- Submit paper for publishing

Thank You,
Asante Sana

Email:
amuthama@kefri.org

Physical and Biotic factors for modelling site selection of Rosewood plantations and seed orchards establishment in Ghana

William Bandoh, CSIR-FORIG




Forestry Research Institute of Ghana

PRESENTATION OUTLINE

- Rationale for the study
- Brief Description of Methodology
- Key Results
- Way Forward

RATIONALE FOR THE STUDY

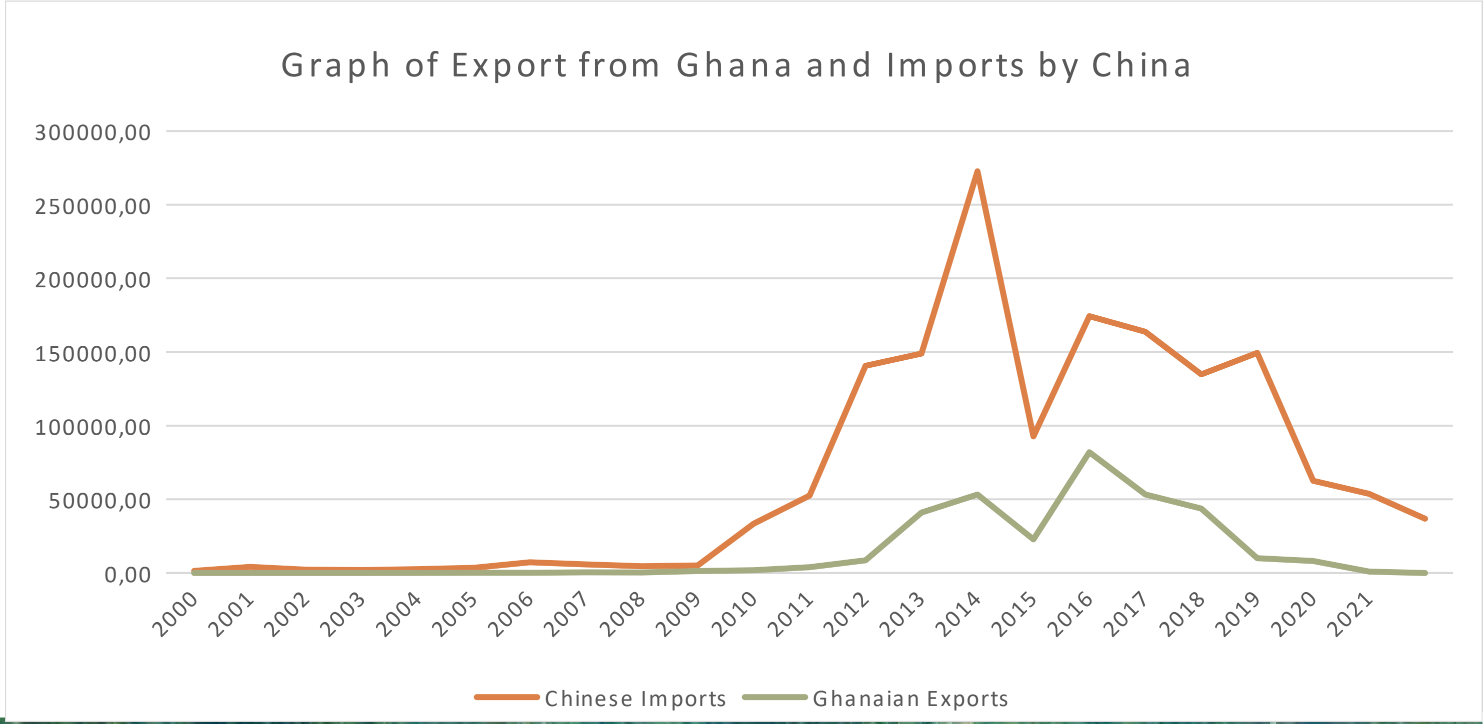
- In line with the theme of Session 5; rosewood forests are facing significant global change risks.

- Rosewood timber is estimated to be the most trafficked and endangered tropical hardwood (including other rosewood species) in the world (Zhu, 2020)

- Over 80% of the world's rosewood supply to China by volume comes from West African savannas (CITIES, 2016).

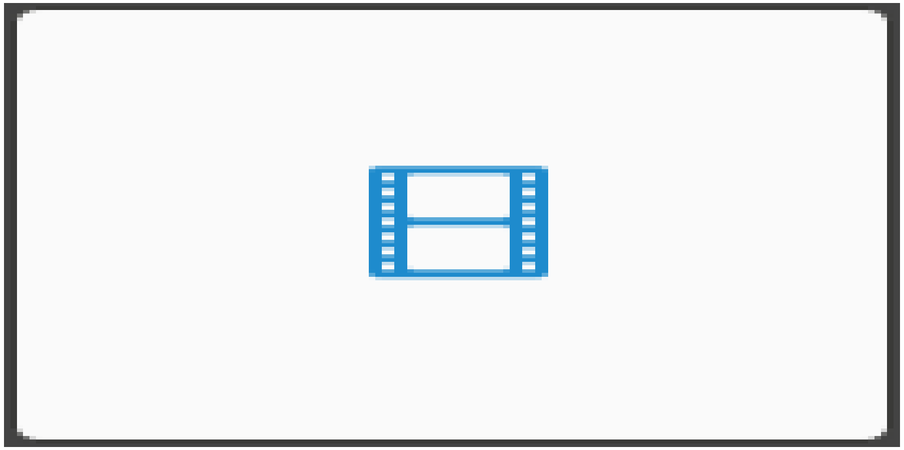
RATIONALE FOR THE STUDY

- The EIA in 2019, estimated that up to 6million rosewood trees had been harvested since 2010
- Majority of the timber harvest & export is illegal



RATIONALE FOR THE STUDY

- As consequence of the high levels of exploitation of rosewood in Ghana, the Forestry Commission of Ghana (FC-Ghana) embarked on a national rosewood planting exercise under its plantation programme



RATIONALE FOR THE STUDY

- FC-Ghana Regional summary of targets and achievements as at June 2021

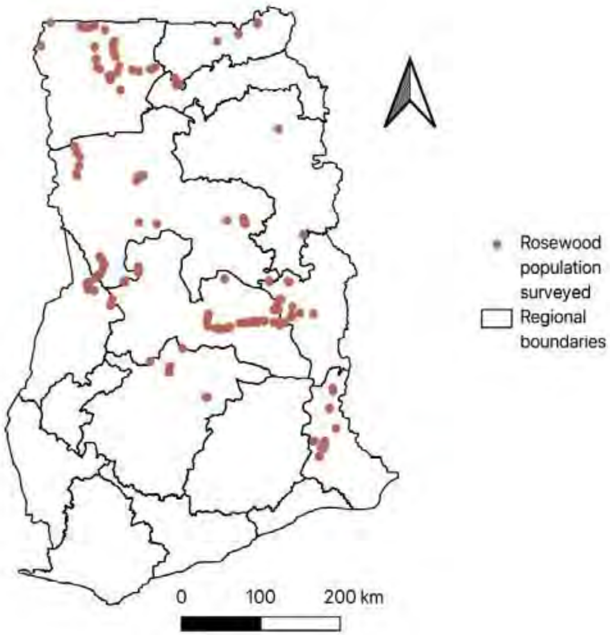
Region	Target	Area Reported(ha)	Area Verified (ha)	Variance (ha)	Variance (%)
Ashanti	24.0	54.0	51.35	-2.65	-5%
Bono	4.0	4.0	4.6	0.6	15%
Bono East	8.0	19.0	12.57	-6.43	-34%
Savannah	16.0	15.0	14.21	-0.79	-5%
Northern	8.0	4.8	4.44	-0.36	-7%
TOTAL	60.0	96.8	87.17	-9.63	-10%

BRIEF METHODOLOGY

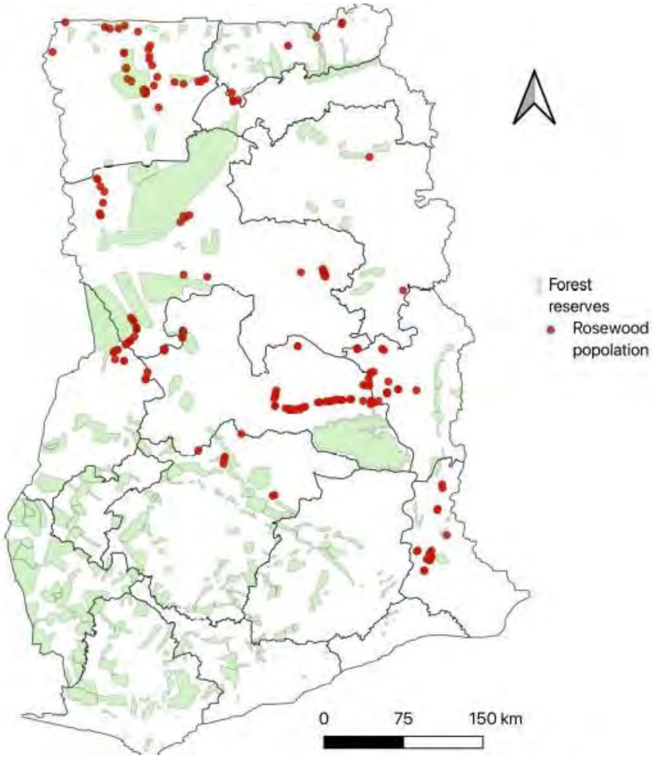
- The study area Ghana is bounded by the coordinates 7°57'9.97" N and -1°01'50.56" W.
- The general suitability maps were generated based on edaphic factors, relative humidity, rainfall and luminance.
- ArcGis & R were used to generate specific maps that addressed seed size, plant health & disease etc
- The multi objective decision making framework was utilised to combine multi criteria methods in selecting the optimal areas for seed orchard & plantation establishment

KEY RESULTS AND DISCUSSIONS

A map of populations of rosewood surveyed across Ghana



How the rosewood sample collection points compare to forest reserves across Ghana



KEY RESULTS AND DISCUSSIONS

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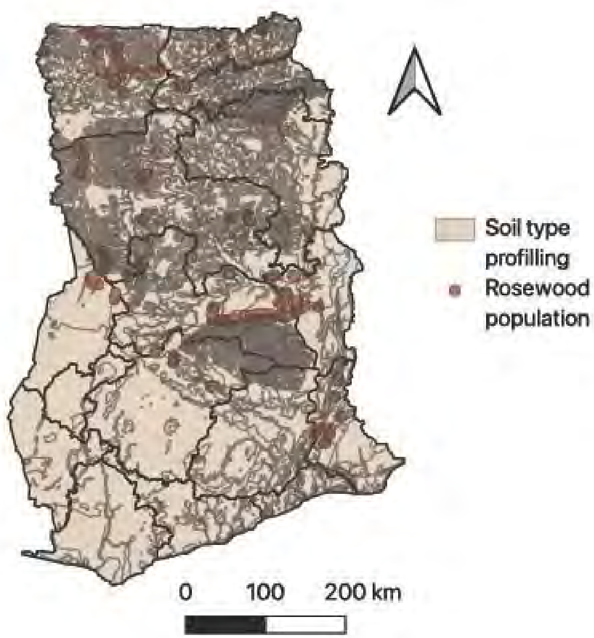
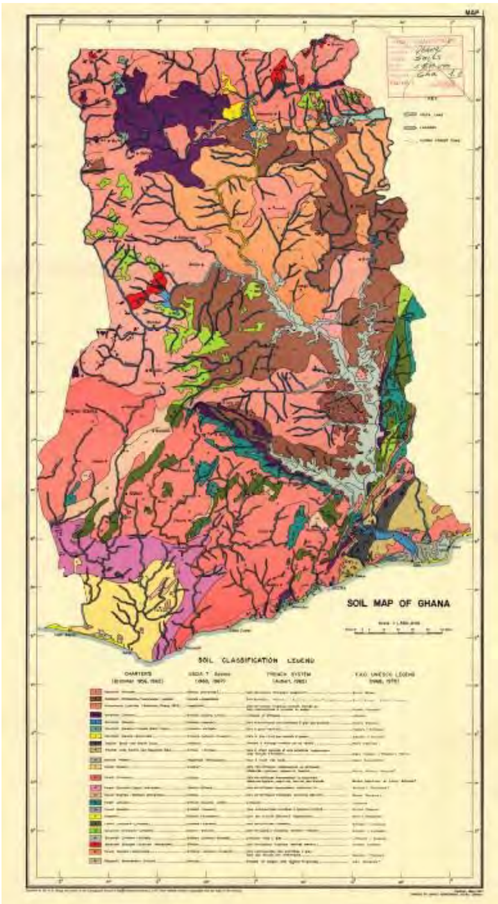
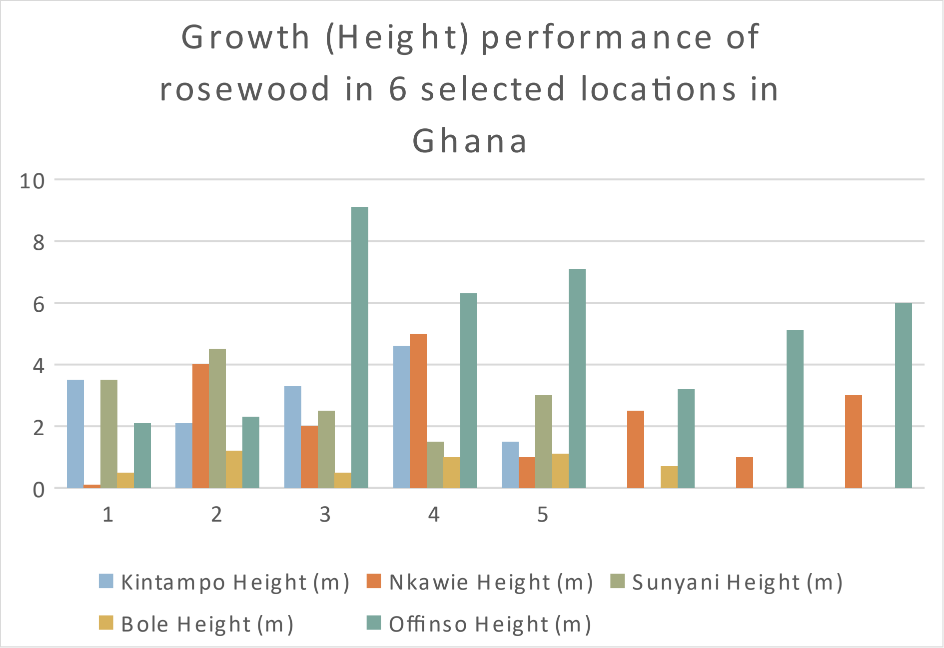


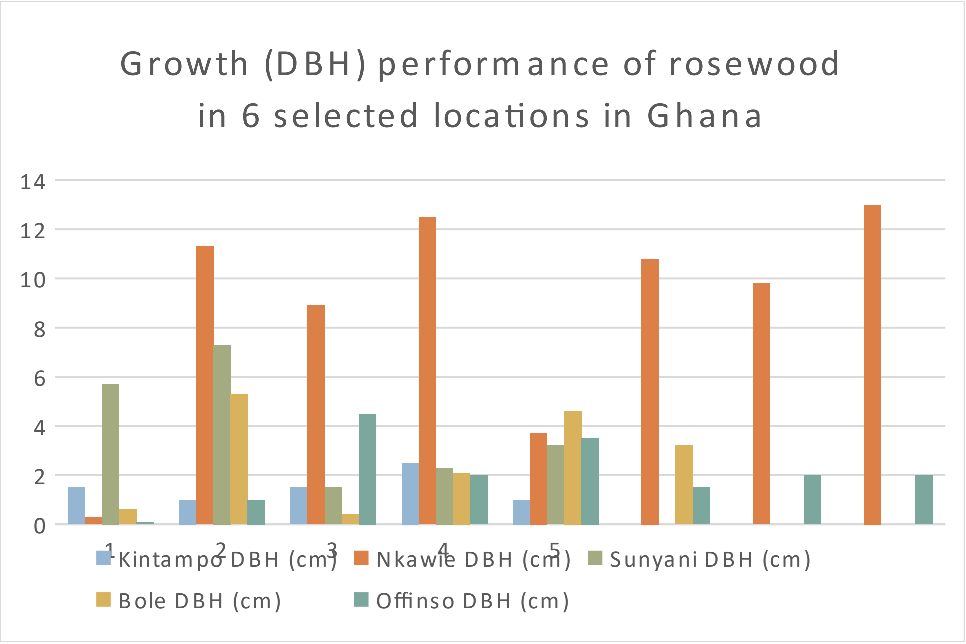
The soil map of Ghana



KEY RESULTS AND DISCUSSIONS

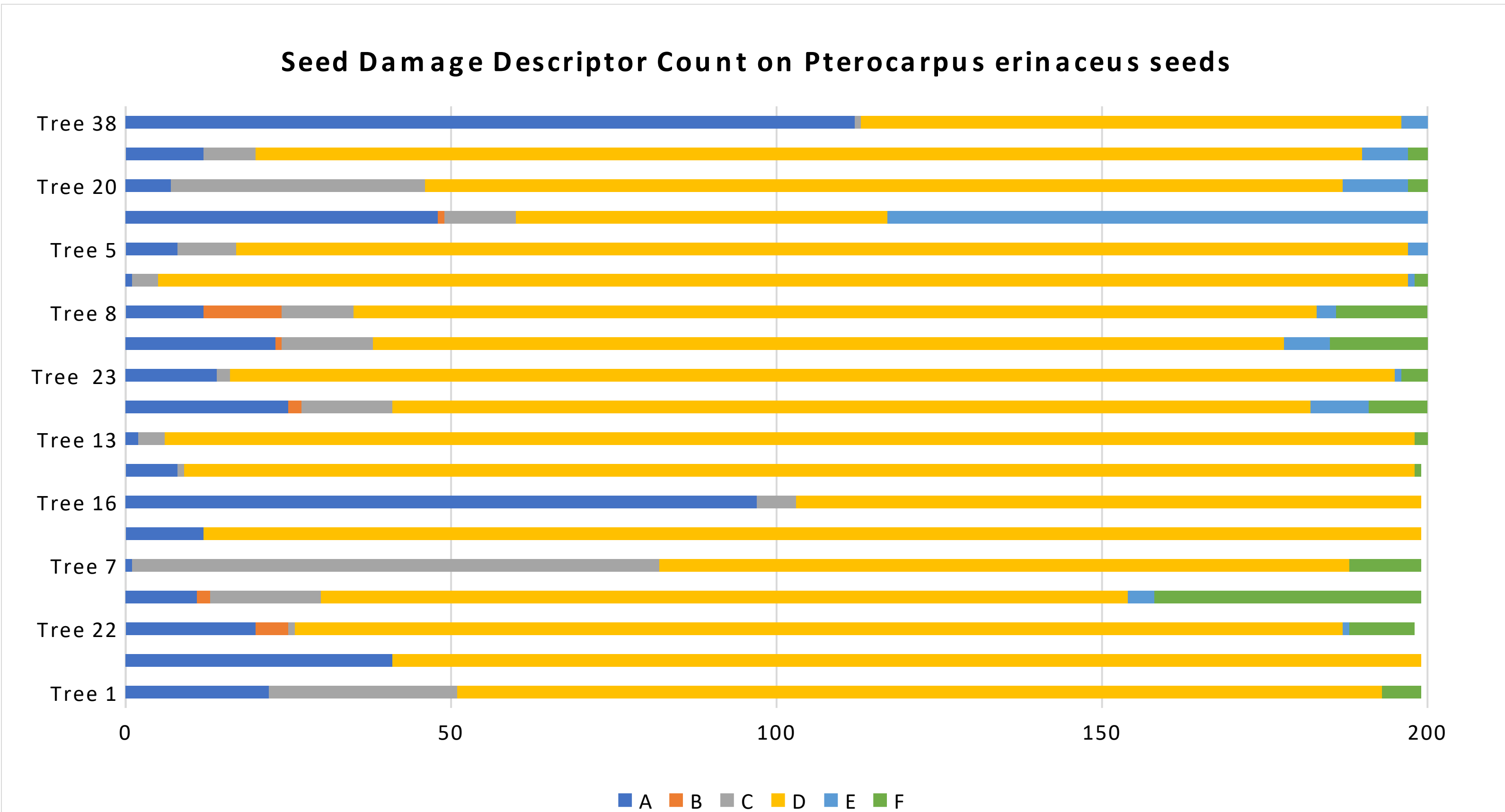
Growth performance characteristics of rosewood in six (6) selected locations





KEY RESULTS AND DISCUSSIONS

Seed Health of rosewood seeds across Ghana: A selection from the DSD



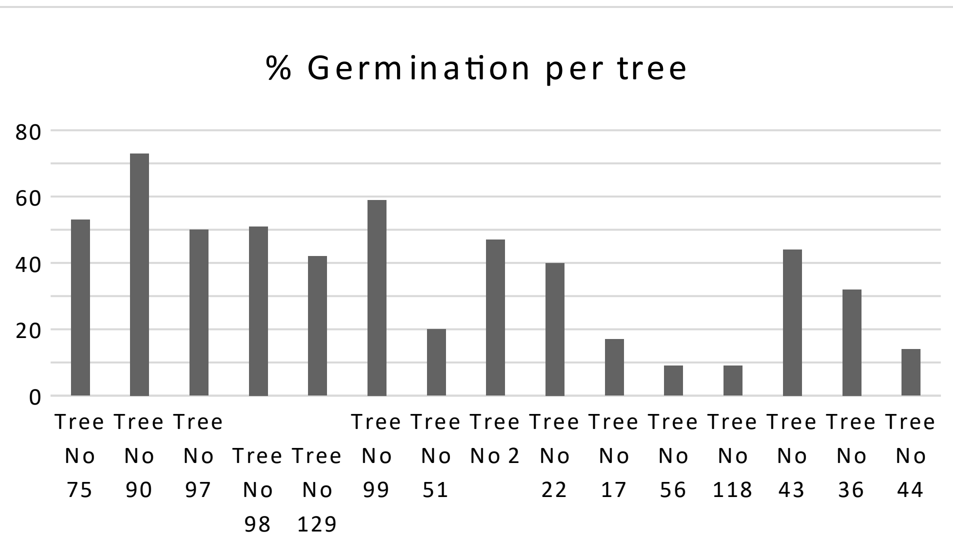
KEY RESULTS AND DISCUSSIONS

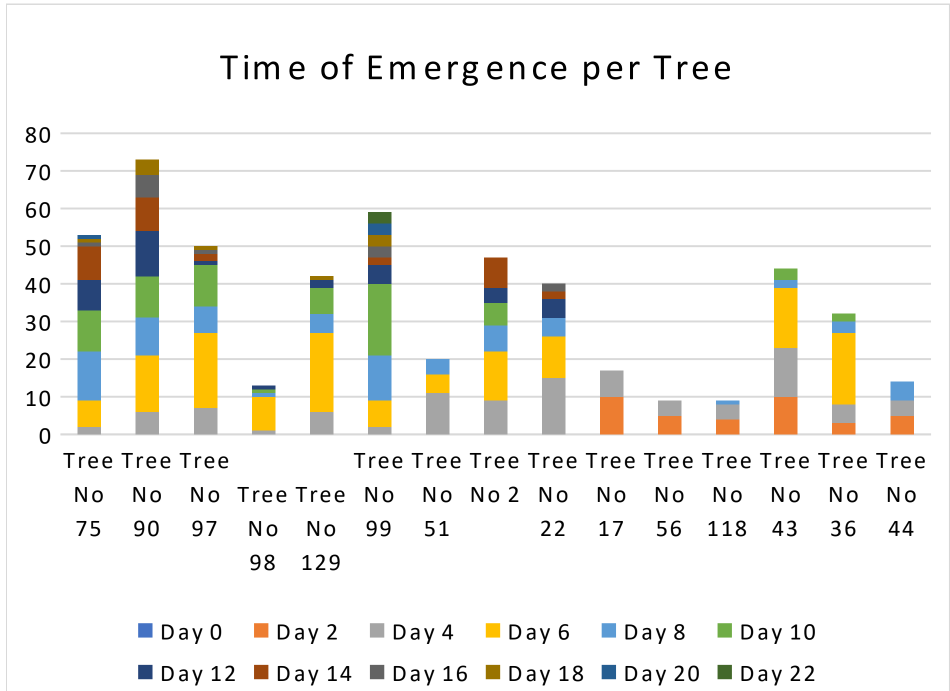
LETTER	DESCRIPTORS
A	Intact seed
B	Underdeveloped seed
C	Blemished seed (discoloured/ not healthy brown)
D	Blemished seed with insect attack
E	Unblemished with insect attack
F	Absent seed

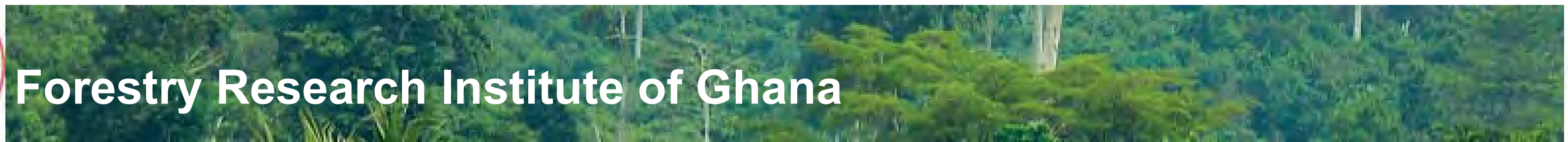
KEY RESULTS AND DISCUSSIONS

Tree 90 showed the highest germination percentage of 80%

On average trees from the savanna showed late emergence

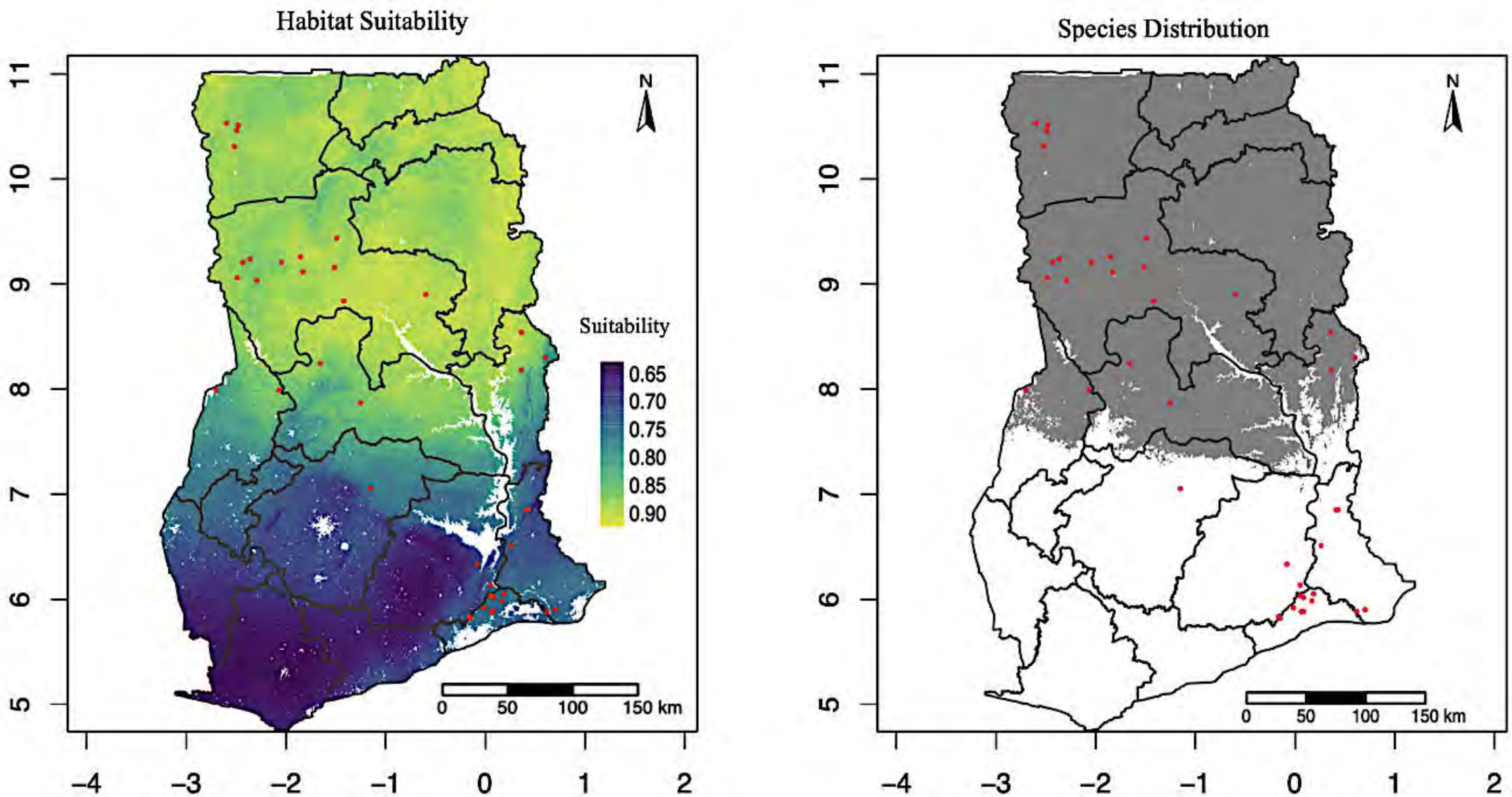






KEY RESULTS AND DISCUSSIONS

The above data and several others have been overlayed to provide this suitability map.



Way Forward

- Comprehensive study of intra & inter specific genetic diversity of rosewood populations in Ghana.
- Research into silviculture of rosewood in the coastal savanna, given that there are few incidences of naturally occuring growth in this AEZ
- Studies into the phenology of the species introduced into the HFZ (MSD & DSD).










Thank You

Forestry Research Institute of Ghana

Way Forward

- This presentation was extracted from our draft manuscript:

  - *Bandoh, W. K. N., Amponsah, J., Mensah, John, Dumenu W. K., Ansah-Boateng, P., Gakpetor, P., Edzesi W. M., Opuni-Frimpon, E., Ofori, E., Torgbor, B., Brown, H., Appiah, R. Physical and biotic factors for modelling site selection of rosewood plantation and seed orchards establishment in Ghana (Unpublished).*

  - *The study was fully funded by the ECOWAS-PARI programme and the CSIR-FORIG*