EFFECTS OF SELECTED ALIEN PLANTS ON RECRUITMENT OF THREE NATIVE TREE SPECIES IN AMANI BOTANICAL GARDEN, TANZANIA

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DISSERTATION SUBMITTED IN PARTIAL FULFILIMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ECOSYSTEMS SCIENCE AND MANAGEMENT OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

Alien plant are plant species introduced in a new area outside their native range and when spread beyond the place of introduction, they become invasive thereby suppressing regeneration of native plants. There is little empirical evidence explaining the effects of the extent of spread of alien plant on regeneration of native tree species. This study was conducted in Amani Botanical Garden (ABG) to assess the effects of selected alien plants on recruitment of native tree species. A combination of a Petri dish experiment and two field experiments were used to assess the effects of allellopathic compounds, and the extent of spread of the selected alien plants on recruitment of native tree species namely *Isoberlinia schefferi*, *Funtumia africana* and *Macaranga capensis*. The results showed that neither invasion stages nor allellopathic compounds had effects on germination of *Funtumia africana*. However, soil organic matter content had positive influence on germination of *Funtumia africana*. There was no significant influence of spread of alien plants on the recruitment of native tree species richness and abundance. Therefore, further studies are recommended to assess the effect of other factors such as light intensity, temperature, predation and thickness of leaf litter on germination of native tree species in Amani Botanical Garden, Tanzania.

DECLARATION

I, **SAMSON SAMSON AMAN,** declare to the Senate of Sokoine University of Agriculture, that this dissertation is my own original work done within the period of registration and has neither been submitted nor being concurrently submitted in any other institution.

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LIST OF ACRONYMS AND ABBREVIATIONS

ABG	Amani Botanical Garden
ANOVA	Analysis of Variance
ANR	Amani Nature Reserve
APs	Alien plant species
CAB	The Centre for Agriculture and Bioscience
CABI	The Centre for Agriculture and Bioscience International
EUCAMP	East Usambara Conservation Area Management Programme
GLM	Generalized Linear Model
GPS	Geographic Positioning System
IAP	Invasive Alien Plant
IUCN	The International Union for Conservation of Nature
PACO	Puertorriqueños Asociados for Community Organization
SDC	Swiss Agency for Development Cooperation
TAFORI	Tanzania Forest Research Institute
TTSA	Tanzania Tree Seed Agency
URT	United Republic of Tanzania
VPO-DOE	Vice President's Office-Department of Environment

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Alien plant are those plant species that are introduced in a new area outside their native range either intentionally or unintentionally by human beings or any other means (Qureshi *et al*., 2014). Some of these plants do spread outside their introduction range and become invasive thereby suppressing native plants (Akhtar *et al*., 2014). The spread of invasive alien plants (IAPs) is recognized as one of the biggest threat to the ecological and economic well-being of the world. About 10% of the world's vascular plants have the potential to invade other ecosystems and affect native biota thus increases cost in conservation (Khan, 2011). For example, in the Southern African Cape, the Government spend about US$40 million per year in controlling IAPs (Matthews and Brand, 2004), while West Africa 70% to 80% of all protected areas are affected in some way by alien plants (IUCN/PACO, 2013). In Tanzania 67 species have been documented as IAPs, of which more than 10 IAP species are found in Amani Botanical Garden (URT, 2014).

Dawson *et al*. (2008) reported that out of the 214 surviving alien plant species with detailed records in ABG, 35 (16%) were regenerating but not naturalised, 38 (18%) had naturalised and a further 16 (7%) had spread to more than 10 compartments, becoming invasive in their new range of introduction thus posing an impact on biodiversity. However, not all alien species are invasive. Richardson *et al*. (2000) suggests that for a species to be invasive it must have spread at 100 m distance in less than 50 years between original plants and second-generation adults for seeded species, and more than 6 m spread over a 3-year-period for vegetative invaders. Thus, it is assumed that the more the spread the species the higher the impact it poses to native plant species.

IAPs affect the understory native regenerating plants in different magnitudes through different growth mechanisms including competition for light (McAlpine *et al*., 2016), soil microorganisms, and allelochemicals (Kuebbing, 2014; Ramgunde *et al.,* 2016). In addition, Qureshi *et al*. (2014) noted that some invasive species are successful because of the effects of allelopathic compounds. Dawson *et al.* (2008) investigated the extent of the spread of alien plant species from their original point to determine their effects on native plant species. Results indicated that 34 species were in their area of introduction and one species had spread into 47 additional points (Figure 1). Thus, the idea of assessing the effect of these invasive species on regeneration of native tree species is interesting and was recommended by Dawson *et al.* (2008).

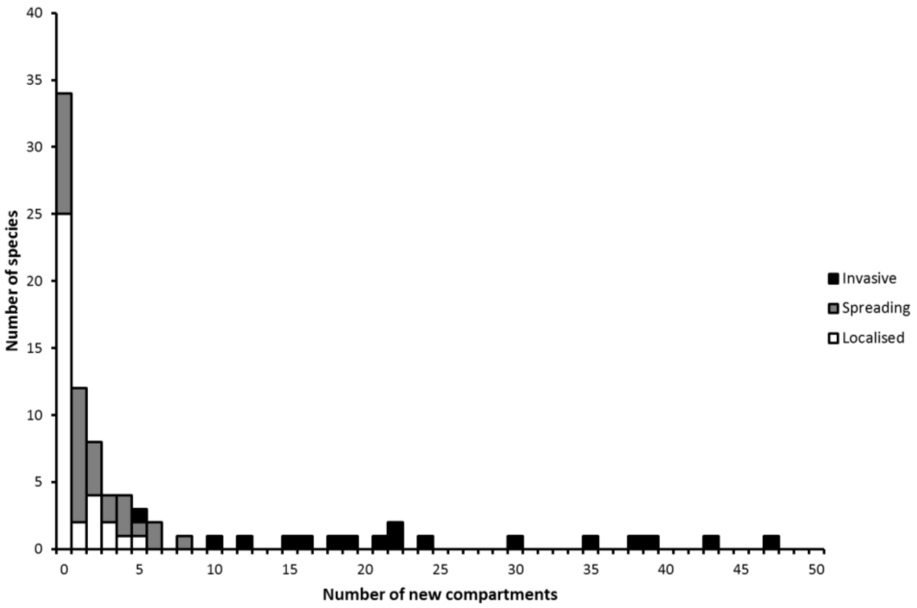

Figure 1: The extent of spread of alien plant species in Amani Botanical Garden, Tanzania.

Source: Dawson *et al*. (2008)

1.2 Problem Statement and Justification of the Study

Threats posed by spread of invasive alien plant species to the existence of natural and managed ecosystems are globally well-studied (Levine *et al*., 2003). In Tanzania, many of these studies have been conducted in Amani Botanical Garden, part of Amani Nature Reserve (ANR) located in the East Usambara Mountains (Edward *et al.,* 2009; Dawson *et al*., 2008). However, there is no clear evidence that regeneration and growth of native plant species is suppressed by the spread of alien plant species (Edward, 2007), thereby threatening the existence of biodiversity in Amani Botanical Garden. Specifically, it is not clear at what stage of invasion does dominance of alien plant species affects the regeneration of native plant species. This study therefore aimed to bridge the knowledge gap by contributing in the understanding of mechanism by which the invasive alien plant species are using to suppress the growth of native plant species (Akhtar *et al.,* 2014; Joshi *et al*., 2015). Amani Botanical Garden found in Tanzania is used here as a case study area.

1.3 Overall Objective

The overall objective was to assess the effects of invasion stages of alien plant species and their associated allelopathic compounds on recruitment, richness and abundance of native tree species in Amani Botanical Garden, Tanzania.

1.3.1 Specific objectives

Specific objectives of the study were to:

i. Assess the influence of spread of alien plant species on richness and abundance of native tree species in Amani Botanical Garden.
ii. Assess the effects of spread of alien plant species on recruitment of native tree species in Amani Botanical Garden.

iii. Assess the effect of allellopathic compounds from alien plant species on germination of native tree species (*Isoberlinia scheffleri, Funtumia africana* and *Macaranga capensis*).

1.3.2 Hypotheses

1. H_0: There is no influence of the spread of alien plant species on species richness and abundance in recruitment of native tree species (e.g. Hulme *et al.,* 2013).

   H_1: The spread of alien plant species have an influence on species richness and abundance in recruitment of native tree species (e.g. Hulme *et al.,* 2013).

2. H_0: The spread of alien plant species does not affect the recruitment of native tree species in Amani Botanical Garden (e.g. Hulme *et al.,* 2013).

   H_1: The spread of alien plants have an effect on recruitment of native tree species in Amani Botanical Garden (e.g. Hulme *et al.,* 2013).

3. H_0: There is no effect of allelopathic compounds on germination of native plants.

   H_1: Allelopathic compounds have a negative effect on germination of native plants.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 An Overview of Invasive Alien Plant Species

Alien plants are plant taxa (synonyms: exotic plants, non-native plants; non-indigenous plants) introduced either accidently or intentionally by human beings (Qureshi *et al*., 2014). An alien species qualifies as an invasive if sustain self-replacing populations for at least 10 years without direct intervention by people (Richardson, 2011). Richardson *et al.* (2000) explained that invasive plants are naturalised plants that produce reproductive offspring, often in very large numbers, at considerable distances from parent plants and thus have the potential to spread over a considerable area and suppress native plants. Among the naturalized alien plants, only small fractions of introduced species become problematic (Hulme *et al.,* 2013). IAPs that may alter plant composition and affect regeneration of native seedlings.

2.2 Effect of Invasive Alien Plants on Regeneration of Native Woody Plants

Alien species especially those that are intentionally introduced may become an invasive by undergoing the following stages: introduction, naturalization, Spreading and being invasive (Dawson *et al*., 2008). Invasive can be detrimental to regenerating native forest because they have the potential to alter forest structure, composition, and function (McAlpine *et al*., 2016). Many form dense vegetative mats that smother native seedlings and reduce native plant abundance and diversity (McAlpine *et al*., 2015). Alien plants are very effective competitors against native species by decreasing their survival and growth. Numerous studies have shown that invasive plant species poses greater effects than dominant native species on the growth and reproduction of native residents (Vila and Weiner, 2004; Vila *et al*., 2011; Kuebbing and Nunez, 2016).

2.3 Mechanism Used by Alien Plant Species to Suppress Native Plants

Alien plants may inhibit native species recruitment through different mechanisms such as allellopathic compounds, shading and soil nutrients (Sun and Junod, 2017). In forest ecosystems some alien species which are shade tolerant such as Syzygium *jambos* and *Psidium cattleianum* are still able to achieve rapid growth despite the low light conditions (Martin *et al*., 2010). When invasive alien plants decrease space, and light the abundance and the diversity of the entire communities may decline. Ehrenfeld, (2003) reported that the mechanism of competition for light, plant-soil feedbacks are also causative mechanism in promoting the invasion of alien plant species.

2.4 Effect of Allellopathic Compounds on Seed Germination

Almost all plants possess allellopathic compounds and are present in many tissues, like leaves, stems, flowers, fruits, seeds and roots (Ramgunde *et al.*, 2016). Many allellopathic compounds have more dramatic effects on seed germination than on the growth and viability of matured plants (Weir *et al.*, 2004). The extent to which allellopathic compound of one plant affect the other plant has been worked out by using one of the other indices like germination percentage, inhibition percentage, germination capacity percentage, germination rate, radicle and plumule length, relative elongation ratio, fresh and dry weight of seedling, root-shoot ratio, and vigour index (Joshi *et al*., 2015;Anjum *et al*., 2010). The released allellopathic compounds by invaders suppress germination, growth and/or reproduction of native inhabitants of the invaded plant community.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted at Amani Botanical Garden (ABG) which is part of Amani Nature Reserve (ANR) located at 5^0 05′ 30" S, 38^0 38′ 10" E in the Eastern Usambara Mountain range of Tanzania. The reserve experiences heavy rains with mean annual rains of 1300 mm in March and May while short rains of up to 1000 mm in October and November. The mean annual temperature ranges from 16.3°C to 24.1°C. The forest vegetation is divided into lowland forest and sub-montane forests (Frontier Tanzania, 2001).

Amani Botanical Garden established in 1902, is one of the oldest Botanical Gardens in Africa, with more than 1,000 species of plants from all over the world. ABG covers an area of 300 ha out of 8 380 ha of the total area of ANR which was Gazetted in 1997 with an objective of protecting biodiversity. The forests form part of a globally recognized biodiversity hotspot and a centre of high endemism and plant diversity. The floristic composition is very diverse and there are 2012 vascular plants species per hector. Approximately 3450 species of vascular plants recorded in the ANR, over one quarter are likely to be endemic or near-endemic. The common tree species in ABG include *Cephalosphaera usambarensis, Allanblackia stuhlmannii, Albizia gummifera, Beilschmiedia kweo, Diospyros abyssinica, Englerodendron usambarense and Drypetes gerrardii.* However, Epiphytic lichens and bryophytes are abundant especially in steep summits.

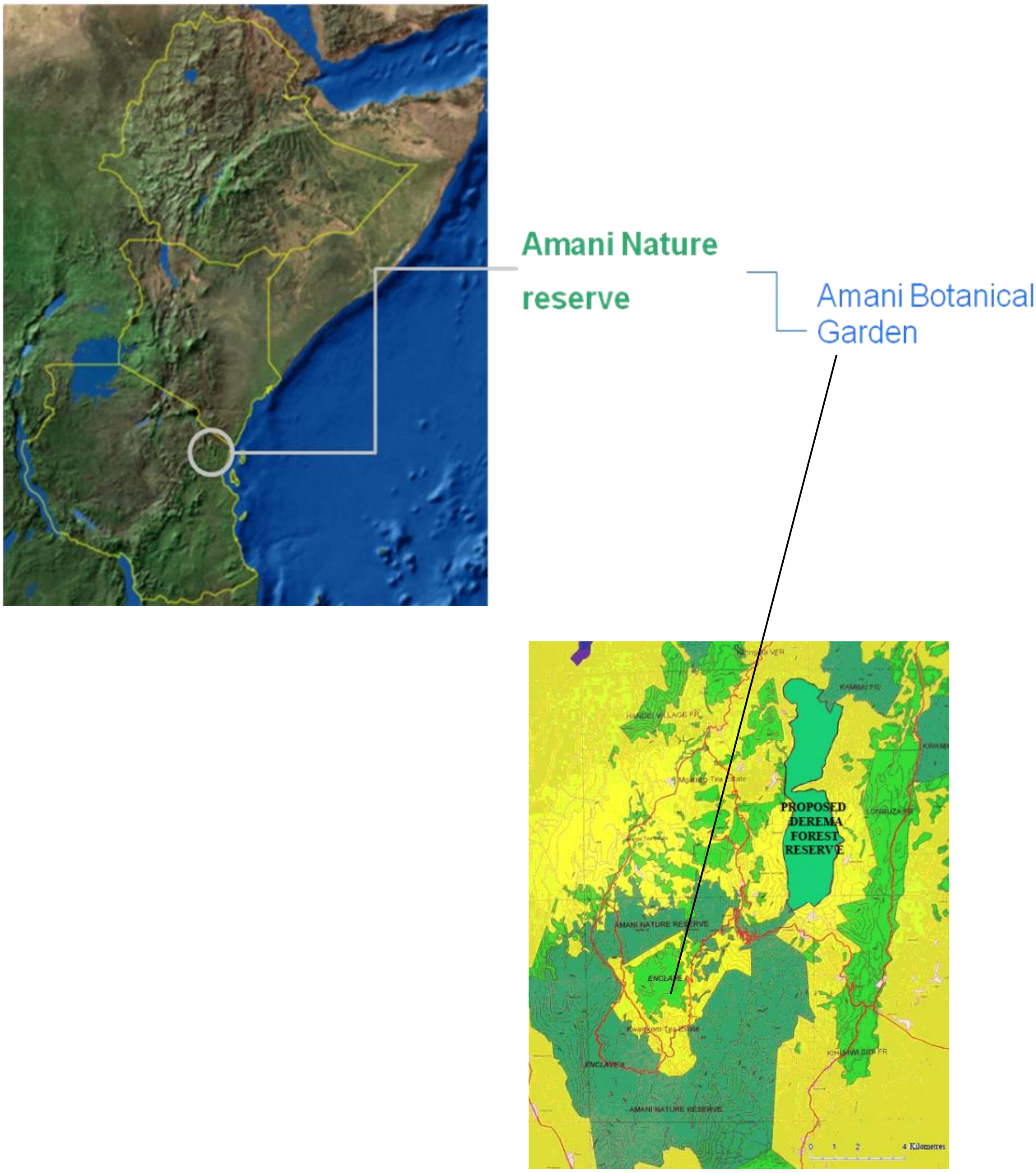

Figure 2: Map of Amani Botanical Garden in Amani Nature Reserve, Tanzania

3.1.1 Research design

Two field experiments and one Petri dish experiment were conducted to address the three specific objectives of this study. Seeds of three native species (*F. africana* tree, Apocenaceae family, *I. scheffleri* tree Fabaceae family and *M. capensis* tree, from Euphorbiaceae) were collected in ABG, with permission from the Conservator, in September 2016. These species were selected for this study because were the only seeds available at the time of collection. Species selected have different ecological characteristic for example, *M. capensis* and *F. africana* are pioneer species (light tolerant) and *I. scheffleri* a climax species (shade tolerant)

3.1.1.1 Field experiments

(a) Effects of invasion stages on germination of native seedling

A sowing seed experiment was set, whereby a total of 19 alien plant species and three native trees species were selected for sowing (Appendix 2). Ten seeds each from *F. africana, I. scheffleri,* and *M. capensis* were sown in different location under each selected 19 alien and three native plant species *F. africana*, *I. scheffleri,* and *M. capensis* making a total of 660 sown native seeds. The 22 plant species were selected to represent the four invasion stages (invasive (seven species), spreading (six species), localized (six species) and native (three species)) and different families to cover the range of Dawson numbers (Appendix 2). Cloth flags were used to mark where each native tree seeds were sown and their locations marked by GPS (Garmin 12) to increases precision in data collection. Assessments of germination status were done after 2 months and the survival status were done after 8 months.

(b) Effects of the spread of alien plant on richness and abundance of native tree species.

In assessing the influence of the spread of alien plant species on regeneration of native plants, the same selected plants that were used in sowing seeds experiment were also used in field experiment. Under each selected alien and native plant a quadrate of 2m x 2 m was established perpendicular to the plant. All native samplings less than one meter found within the quadrate were identified, counted and recorded (Appendix 3).

3.1.1.2 Petri dish experiment: Effect of allellopathic compounds on germination of native tree species

Petri dishes experiment was conducted to test the effects of allelopathic compounds on germination of native tree species. Soil was collected underneath of 15 selected plant species (12 alien plant and three native tree species) comprising four-invasion stages (Appendix 4). There were four replicates per soil origin. Activated Carbon with concentration of 4ml/L were mixed with soil from each replicate collected under the 15 selected plant species to absorb allelopathic compounds.

Plate 1: Adding activated carbon into petri dish containing soil from four invasion stages to allow absorption of allelopathic compounds at Lushoto Forest Research Institute laboratory, Tanzania.

Measuring cylinder 25 ml were used to measure the amount of activated carbon required to be used in petri dish experiment. Activated carbon were added at a concentration of 20 ml/L to half of the petri dishes that were set for experiment (Plate 1) to absorb organic compounds (Murrell *et al*., 2011). 4ml of activated carbon were mixed with soil to each replicate then watered and left in 24 hours to allow soil to absorb activated carbon (Plate 2). Petri dishes were arranged randomly on a laboratory table at Lushoto Forest Research Institute in Tanzania (Plate 3) so as avoid biasness in manipulation and assessment.

Plate 2: Watering petri dish containing soil with activated carbon to allow soil to absorb activated carbon before sowing seeds in the laboratory at Lushoto Forest Research Institute, Tanzania

Three seeds of *F. africana* and *M. capensis* and one of *I. scheffleri* were sown per petri dish. Each petri dish was sown with only one type of native tree seeds. Before sowing, samples of the seeds were tested at Tanzania Tree seeds Agency (TTSA) at Lushoto for seed viability using the cutting test method. Viable seeds were whitish where by unviable seeds were dark brown and somewhat rotten. The number of germinated seedlings in each petri dish were counted and recorded for 90 days from the date the experiment was set.

Plate 3: Arrangements of Petri dish experiments in the laboratory at Lushoto Forest Research institute, Tanzania

A total of 360 petri dishes and 840 seeds were set for experiment to assess germination based on invasion stages, soil origin and activated carbon as experimental factors. Data collected from Petri dish experiment were filled in collection data sheet (Appendix 5).

3.2 Soil Data Collection

Soil samples were collected under the twelve alien plants and three native plants and stored in a refrigerator before analysis of soil chemistry parameters. The following soil parameters were analysed: Total Nitrogen, Organic carbon, Sodium, Potasium, Phosphorus Bray, Calcium, Magnesium, pH_20, pH_20.Kcl, Electro-conductivity and Cation Exchange Capacity at Mlingano laboratory in Muheza District, Tanzania to assess their effects on germination and recruitment of native tree species.

3.3 Data Analysis

To examine the effect of spread of alien plants invasion stages on native trees species recruitment, simple ANOVA was used to compare samplings and Dawson number means from the four invasion stages. Poisson Regression and Pearson correlation coefficient were used to determine the relationship between number of germinated native tree species and soil nutrient availability.

The effect of activated carbon on the number of germinated seeds in Petri dish experiment was analysed using a generalised linear model with the number of germinated seeds as response variable, presence or absence of activated carbon as explanatory variables.

Data from field experiment were analysed using a generalised linear model with quasipoisson distribution because of the large number of instances where no seedlings were found. Since only *Funtumia africana* germinated of all the three native species sown in both petri dish and field experiment therefore was the only specie considered for further analysis. The number of germinated seedlings and surviving seedlings were response variables and the extent of spread and native tree species explanatory variables. All data collected were analysed using Minitab software version 17.

CHAPTER FOUR

4.0 RESULTS

4.1 Effects of Invasion Stages on Native Seedlings Germination

A total of 82 native seeds (8.5%) germinated in field experiment and among them 19 (1.7%) survived for more than eight months (Table1). Results showed no significant differences in germination of *F. africana* under trees of different invasion stages (P=0.221; Table 2). Further investigations were done on altitude and Dawson's number. However, no significant effects were found (P = 0.531 and 0.087; Table 2) for Dawson's number and altitude respectively.

Table 1: The number of sown native seeds, emerged saplings and saplings surviving for eight months under selected alien and native plants in Amani Botanical Garden, Tanzania

S/N	Native tree species	Seeds sown	Seeds germinated	Percentage germination	Saplings survived	Percentage survived
1	*Funtumia africana*	220	56	68.29	17	89.48
2	*Isoberlinia scheffleri*	220	12	14.64	1	5.26
3	*Macaranga capensis*	220	14	17.07	1	5.26
	Total	**660**	**82**	**100**	**19**	**100**

Table 2: Effect of invasion stages, Dawson number and altitude on *Funtumia africana* germination into the field experiment in Amani Botanical Garden, Tanzania

Source	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Invasion stages	3	4.408	1.469	4.41	0.221
Error	24	69.145	2.881		
Dawson Number	1	0.3926	0.3926	0.39	0.531
Error	20	58.7355	2.9368		
Altitude	1	2.936	2.936	2.94	0.087
Error	20	56.192	2.810		

4.2 Effect of Allellopathic Compounds on Germination

Out of 840 seeds that were sown only 128 seedlings germinated in the petri dish experiment (Table 3). Of these, 127 seedlings were from *Funtumia africana* and one was from *Macaranga capensis*. The germination rate of *F. africana* was 1.0 ± 0.1 seeds per petri dish, or one third of the sown seeds. The regression analysis indicated that activated carbon did not have a significant effect on germination of *F. africana* (P = 0.517; Table 4; Figure 3). There was no significant effect of soil from alien tree species of different invasion stages on germination rate of *F. africana* (P = 0.747; Table 4; Figure 4). Since no significant effect of activated carbon or invasion stages on germination of *F. africana* was found, the study investigated also the effect of soil nutrients on germination of *F. africana.* There was a relatively low correlation (about 37%) between number *F. africana* seedlings germination and soil total nitrogen and organic carbon content, which was slightly higher compared to other soil elements (Table 5). However, regression analysis revealed that only organic carbon content had a positive significant relationship with number of germinated *F. africana* seedlings (P = 0.022; Table 6; Figure 5), explaining 13% of the variation in the *F. africana* seedling germination (Table 5).

Table 3: Number of native seeds germinated in petri dishes in laboratory at Lushoto Forest Research Institute, Tanzania

Native seeds	No. of Petri dish	Germination	Seeds sown	Seeds germinated
Isoberlinia scheffleri	120	0	120	0
Funtumia africana	120	85	360	127
Macaranga capensis	120	1	360	1
Total	**360**	**86**	**840**	**128**

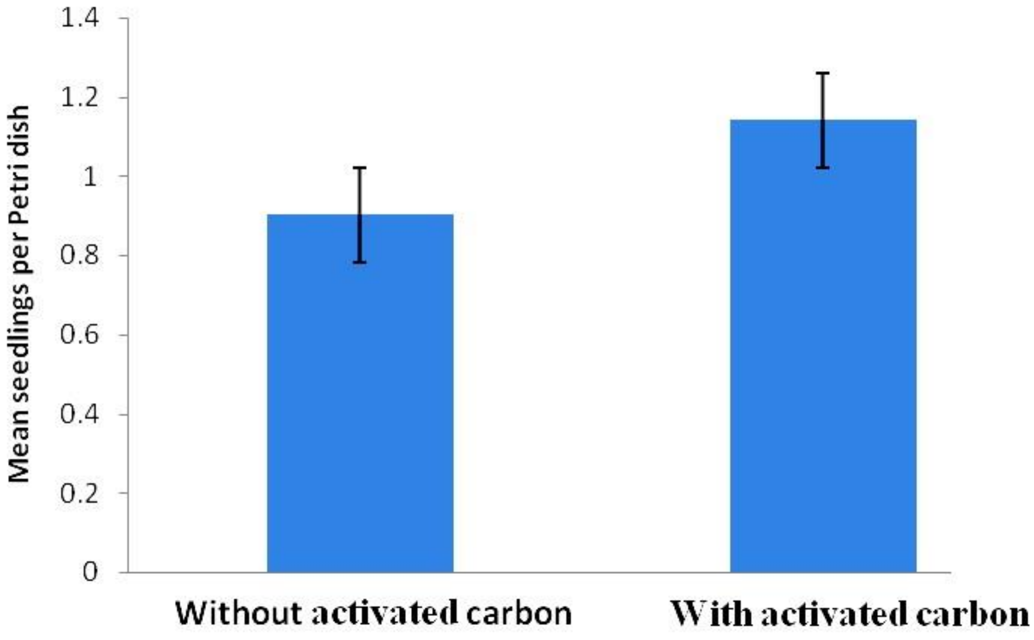

Figure 3: Germination mean of *Funtumia africana* in petri dishes with soil collected from under 12 alien and 3 native tree species in Amani Botanical Garden, Tanzania. Error bars represents ± 0.1 SE.

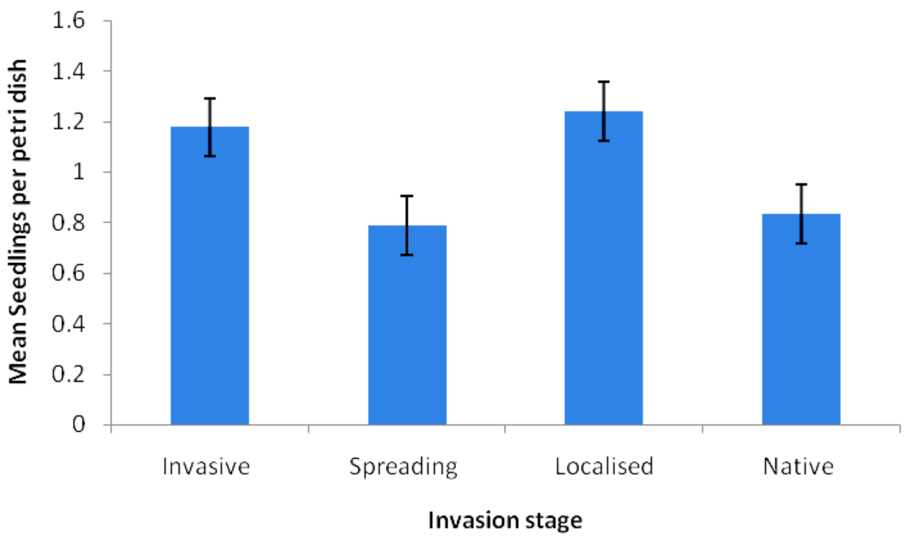

Figure 4: Mean and invasion stages of alien tree species on germination of *Funtumia africana* in petri dishes with soil from under selected alien and native plant species in Amani Botanical Garden, Tanzania. Error bars represents ± 0.1 SE.

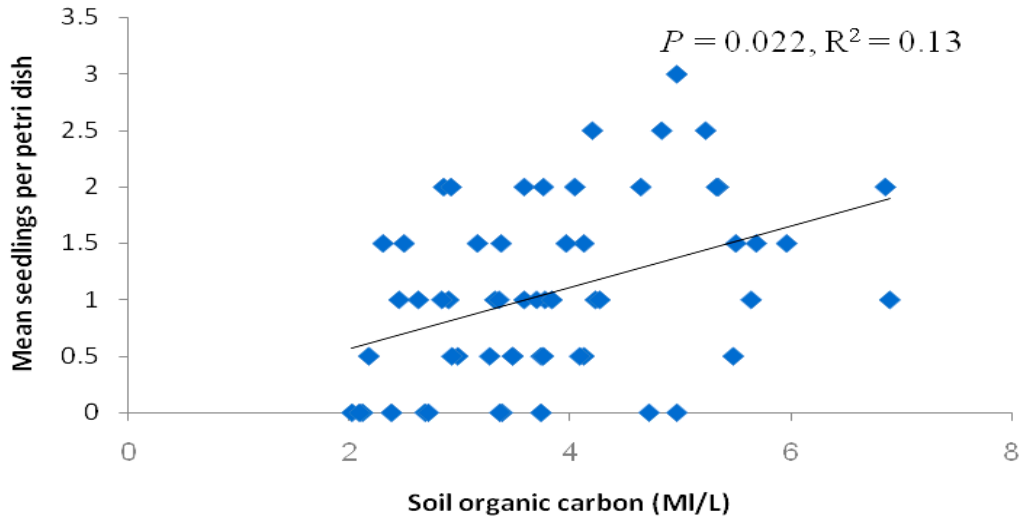

Figure 5: The significant positive relationship between germination of *Funtumia africana* seeds and soil organic carbon from 12 alien plants and 3 native trees in Amani Botanical Garden, Tanzania.

Table 4: The summary of the Poisson regression analysis between mean germination of *Funtumia africana* and both invasion stages and allellopathic compounds in Amani Botanical Garden, Tanzania.

Source	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Activated carbon	1	0.4199	0.4199	0.42	0.517
Invasion stage	3	1.2236	0.4079	1.22	0.747
Error	25	13.2646	0.5306		

Table 5: Correlations coefficient between germination of *F. africana* and soil parameters in Amani Botanical Garden, Tanzania

Abiotic parameters	***Funtumia. africana* mean Germination**
Altitude	0.17
Total Nitrogen	0.34
Organic carbon	0.38
Sodium	0.15
Potassium	0.19
Phosphorus. Bray	-0.03
Calcium	0.06
Magnesium	0.02
pH.H2O	-0.02
pH.KCl	0.02
Electroconductivity	0.19
Cation Exchange Capacity	0.02

Table 6: The summary of the Poisson regression analysis between of mean germination of *Funtumia africana* and soil organic carbon in Amani Botanical Garden, Tanzania

Source	**DF**	**Adj Dev**	**Adj Mean**	**Chi-Square**	**P-Value**
Organic Carbon	1	5.246	5.2457	5.25	0.022
Error	56	36.159	0.6457		

Table 7: Mean variation soil nutrients of trees from different invasion stages in Amani Botanical Garden, Tanzania

Species	Invasion stages	Total Nitrogen in percentage (%)	Soil organic carbon in Percentage (%)
Arenga pinata	Spreading	0.20 ± 0.01	2.59± 0.11
Albizia saman	Localised	0.29 ± 0.03	3.20 ± 0.37
Cordia alliodora	Invasive	0.24 ± 0.01	3.47 ± 0.26
Creptomeria japonica	Localised	0.34 ± 0.02	4.64 ± 0.37
Elaeis guineensii	Invasive	0.26 ± 0.02	3.19 ± 0.40
Funtumia africana	Native	0.38 ± 0.01	4.45 ± 0.32
Ficus elastica	Localised	0.29 ± 0.04	3.59 ± 0.40
Hura crepitans	Localised	0.33 ± 0.03	3.77 ± 0.49
Hovenia dullis	Spreading	0.30 ± 0.02	4.41 ± 0.51
Isoberlinia scheffleri	Native	0.49± 0.10	5.90 ± 0.50
Macaranga capensis	Native	0.25 ± 0.04	3.57 ± 0.46
Maesopsis eminii	Invasive	0.36± 0.02	5.49 ± 0.46
Phyllostachys bambusoides	Invasive	0.25 ± 0.03	3.13± 0.20
Psidium cattleianum	Spreading	0.25 ± 0.02	3.42 ± 0.22
Syzygium jambos	Spreding	0.24 ± 0.03	3.22 ± 0.46

4.3 Effects of Invasion Stages, Dawson Number and Altitude on Species Richness and Abundance

A total of 609 individuals, belonging to 120 species were found growing under 22 alien selected plants species. Out of 120 sapling species the largest fraction (43.33%) were found under invasive plants while the least (12.50%) under spreading plants (Table 8). Among four invasion stages**,** the invasive stage had the highest number of saplings (35.14%) than other invasion stages and the least were in spreading stage (5.75%; Table 8). Results indicated that invasion stage had an influence on both species richness and abundance in Amani Botanical Garden (P=0.001; 0.001; Table 9; Figure 6 and 7).

Table 8: Species richness and abundance of saplings found under selected alien and native plant species in Amani Botanical Garden, Tanzania

S/N	Invasion stage	Species richness	Percentage (%)	Abundance (number of individuals)	Percentage
1	Invasive	52	43.33	214	35.14
2	Spreading	15	12.50	35	5.75
3	Localized	32	26.67	186	30.54
4	Native	21	17.50	174	28.57
	Total	**120**	**100**	**609**	100

Table 9: Results from Poisson regression analysis showing the relationships between tree species richness, abundance and invasion stages in Amani Botanical Garden, Tanzania

Source	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Species richness					
Invasion stage	3	17.31	5.770	17.31	0.001
Error	18	18.55	1.030		
Abundance					
Invasion stage	3	154.3	51.43	154.29	0.001
Error	18	460.3	25.57		

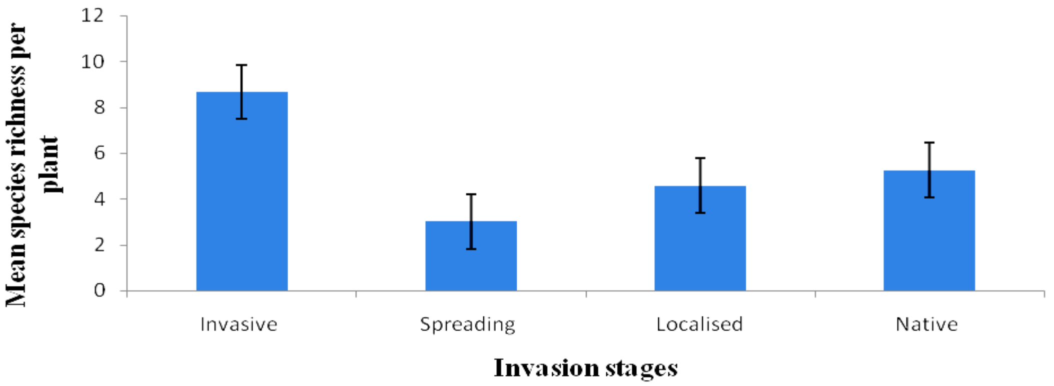

Figure 6: Species richness found under selected alien and native plant species in four invasion stages in Amani Botanical Garden, Tanzania. Error bars represents ± **0.1 SE**.

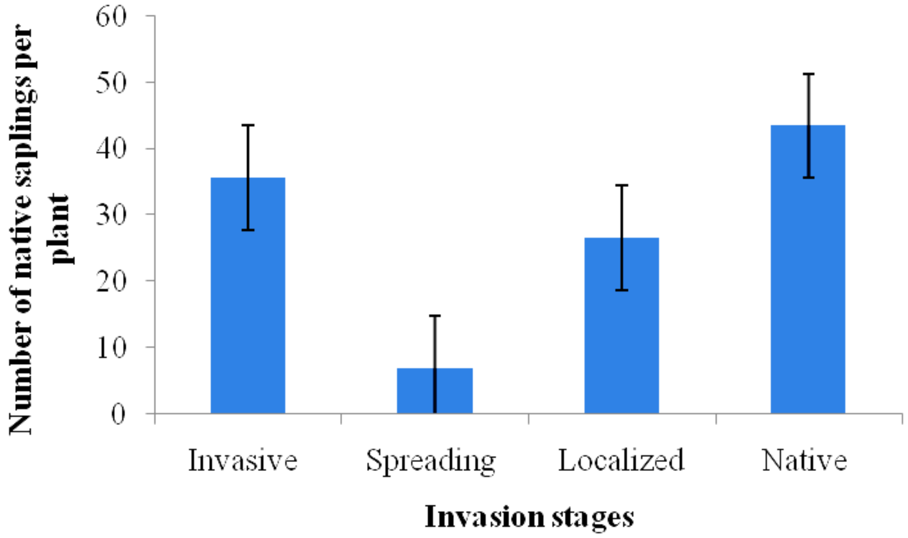

Figure 7: Native sapling species found under selected alien and native plant species of four invasion stages in Amani Botanical Garden, Tanzania. Error bars represents ± 0.1 SE.

CHAPTER FIVE

5.0 DISCUSSION

This study was carried out to assess whether there is a relationship between invasion stages of alien plant species and species richness and abundance of native tree species in Amani Botanical Garden. Specifically, the study sought to assess the relationship between the extent of spread of alien plant species in Amani Botanical Garden and recruitment of *I. scheffleri, F. africana* and *M. capensis;* and assessed the effect of allellopathic compounds from alien plant species on germination of *I. scheffleri, F. africana* and *M. capensis.*

5.1 Effects of Invasion Stages on Native Seedling Germination

Findings from this study showed that only *F. africana* germinated, probably due to its ability to the quick establishment taking advantage of any disturbance in the forest. Ecologically *F. africana and M. capensis* are pioneer species in ABG (Muhanguzi, 2002). Previous studies indicate that pioneer species often lie dormant in the soil seed bank consequently disturbances promote their germination (Muhanguzi *et al.*, 2005). Another reason could be due to the size of the seeds whereby *F. africana* seeds are small in size, 3.5-7.5 cm long and 0.2-0.6 cm wide with a light outer coat facilitated germination. Also, seeds were sown in soil depth of 1-3 cm, which allowed absorption of moisture more easily thus stimulated germination. According to Mukhongo *et al*. (2011), seeds that are small sown between 0 to 5 cm soil depths, germinated easily when conditions were favorable. Samuel *et al*. (2005) reported that the strongest inhibition of native trees occurs during the germination and emergence stage, ultimately affects its recruitment and establishment. Muhanguzi *et al*. (2005) explained that seed germination, emergence, growth and survival of seedlings affect forest regeneration by influencing plant populations in tropical forests. However, seed germination may be affected by their ecological and biological traits, plant invasion, predation, soil moisture content, light intensity and other environmental factors.

Nevertheless, according to Thijs (1993) light can stimulate and/or inhibit seed germination. Since *F. africana* did not germinate in dense vegetation light quality and intensity could also be one of the factors which influence germination of its seeds (Fenner, 1980; Drake, 1993).

Very few *M. capensis* germinated probably because of their phenotypic, biological and ecological characteristics. Burying *M. capensis* could be another reason for poor germination and perhaps created unfavorable germination condition for *M. capensis*. Many forest and fruit tree species especially from tropical region produce seeds that are damaged by desiccation (Msanga, 2007), seeds that undergo no, or only little maturation drying as the final phase of development. Since *M. capensis* were collected with their fruits, they possibly had not reached extensive drying maturation. In addition, seeds from *M. capensis* had several seed coat endocarps that required adequate water and time to have a complete physiological germination development. According to Dorne (1981) and Msanga (2007), germination of intact seeds is prevented by the seed coat, which prevents moisture content absorptions as well as dehydration. When seeds are dehydrated, there is a water content level below which they lose viability (Pierre *et al.,* 2017). The study did not observe any germination from *I. scheffleri* probably because of its size (big) which possibly attracted predators such as rodents as reported by previous studies (Obiri *et al*., 2005; Mukhongo *et al*., 2011).

Germination plays a central role in the life cycle of plants and therefore could be a key trait in determining species invasiveness (Ferreras *et al.*, 2015). Results indicated that none of the three attributes (invasion stages, altitude and Dowson number) affected germination of *F. africana* hence failed to support the hypothesis established. This is in line with Haiyan *et al.* (2007) who also found a significant negative correlation between germinability and altitude when studying seed mass and germination in an alpine meadow on the eastern Tsinghai–Tibet plateau.

Similarly, although field experiment results showed that invasion stages had some mean variations but no clear pattern were observed, this implies that variation possibly were due to the traits of individual plants not the invasion stages. Kisa *et al.* (2007) explained that some alien species caused more or less soil changes that led unfavorable condition to the establishment of native species

Furthermore, it was revealed that to whatever extent alien plants are spread away from their original plot of introduction no effect was attributable to germination of native tree seeds in ABG. No evidence was found to support that the extent of spread of alien plants affected germination of *F. africana*. This result is in line with Chauhan and Nautiyal (2007) who reported that germination is affected by optimum conditions of light, dark, temperature, hormonal treatment, soil composition, depth of soil seed sown.

5.2 Effect of Allellopathic Compounds on Germination of *F. africana*

There was no sufficient evidence to support hypothesis that allellopathic compound do not affect germination of *F. africana* in ABG. This finding aligns with Prati and Bossdorf (2004) who reported that activated carbon increased germination by 14%, they further clarified that if invasive species release allelopathical compounds that suppress germination; they do so to a similar degree as the native plant community. Similarly, Fabbro *et al.* (2014) supported that activated carbon generally enhanced seed germination.

The effect of activated carbon was mediated by soil microorganisms which influence germination and plant growth (Philippot *et al*., 2013; Sun and Junod, 2017). This opposes Loydi *et al*. (2015); Chu *et al*. (2014); and *Zhang et al.* (2016) who reported that allellopathic compounds may affect germination and establishment of native tree species. It is assumed that allelopathic compound produced by plants from different plant regions inhibit germination and growth of other plants species. The allelopathic effects of *Prosopis* have also been shown to reduce native tree germination and survival (de Souza Nascimento *et al*., 2014; ElEl-Keblawy and Abdelfatah, 2014). However, this study found that allellopathic compounds do not affect germination; perhaps other mechanisms such as competition for nutrients, light and moisture content.

5.3 Influence of Soil Nutrients on Germination

There was substantial variation in soil parameters among the four invasions stages. Total nitrogen and organic compounds showed some correlations with germination (Table 5) However, result indicated only organic carbon had positive relation on germination of F. africana. It was also found that only 13% of variation in germination of F. africana is explained by soil organic carbon that is among of factors influencing soil moist content drivers for seed germination. Other study shows that soil moisture positively affect seed germination (Dechoum *et al*., 2015) whereas plants nutrient uptake can only occur when soils are moist (Leffler and Ryel, 2012; Belnap *et al*., 2016).

5.4 Influence of Spread of Alien Plants on Species Richness and Abundance of Native Tree Species

Results indicated that invasive significantly affect both species richness and abundance of native tree species (Figure 6 and 7) probably was due to competition for recourses. Literature shows that invasive are not always more competitor than native (French *et al.*, 2017) their competitive performance at low densities may be relatively weak if those native plants have priority access to limited resources (Kardol *et al*. 2013; Mason *et al*. 2013; Panetta and Gooden, 2017). The pioneer tree *Maesopsis eminii* is the most well known and wide spread invasive alien plant in ABG (Dawson *et al*., 2008) thus its impact on native species richness and abundance was higher than the localized species due to soil plant feedback facilitating coexistence (John *et al.,* 2016). Considering that different species respond uniquely to different environmental factors and that each species will survive where condition allow them to grow (Mnishi *et al.,* 2007; Edward *et al*., 2009) sometimes invasions can change environmental factors hence suppressing recruitment of native species. Successful invaders have few enemies than natives (Edward *et al.*, 2009); thus can compete effectively with native species (Vila and Weiner, 2004) However, native species appear to have a competitive advantage over invasive species in low-resource systems (Funk, 2013).

Augspurger (1984) noted that light strongly influences regeneration of some tropical tree species. Similarly, this study did not record any sapling species under *Phyllostachys bambusoides, Psidium cattleianum* and *Arenga pinnata* due to high shade and thickness that could not allow light to penetrate to support life for other species. Ultimately has resulted the whole area to have a mono-dominant form of vegetation that affects the ecosystem services. Equally, Rajaonarimamy *et al.* (2017) reported that invaded areas decreases diversity and abundance of native plants species.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study found that invasion stages, Dawson number and altitude do not have affect on germination of *F. africana* in Amani Botanical Garden. Although mean variation in germination were observed but no trend pattern were found between germination and the invasion stages. Altitude, which influences temperature and moisture content, showed no significant effect on germination of *F. africana*.

The study further investigated the effect of alien plant invasion on recruitment of other native tree species beyond *F. africana* by increasing number of selected plants to study from 15 to 22 plant species. However, there were no relationships found between the extent of spread of alien plant and the recruitment of other native tree species in ABG.

The extent of spread of alien plant species affected significantly native species richness and abundance in Amani Botanical Garden. Invasive had more species richness and abundance than the localized species. Literature indicates that a number of species spreading at ABG are known to exhibit shade tolerance, such as *Syzygium jambos* (CAB International, 2005) and *Psidium cattleianum* (Cronk and Fuller, 1995). None of native saplings species were recorded under *Syzygium jambos* and *Psidium cattleianum* in ABG.

Results from both field and Petri dish experiments suggested that invasion and allelopathic compound had no effect on native tree seeds germination. Since allellopathic compounds and invasion stages had no influence on seed germination, the study tested soil parameters from selected plant species to investigate their influence on germination of

F. africana in ABG. It was found that soil organic carbon content that is highly associated with moisture content availability was among of the limiting factor for germination of *F. africana* in Amani Botanical Garden

6.2 Recommendations

Seed germination is one of the key plant processes in plant lifecycle. Based on the findings of this study further studies are recommended to assess the influence of other factors such as light intensity, temperature, predation and leaf litter on germination of native tree species in ABG. Finally, the management should make deliberate effort to uproot or clear *Arenga pinnata* and *Phyllostachys bambusoides* to control their spread by replant with native tree species to reduce effect of monospecific stands which affects biodiversity of the area by distressing ecosystem services supply chain.

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APPENDICES

Appendix 1: Definition of terms (Glossary)

Alien plant; an organism occurring outside its natural past or present range and dispersal potential, whose presence and dispersal is to the result of intentional or unintentional human action (Hulme, 2011).

Plant introduction; direct or indirect movement, by human agency, of an organism outside its past or present natural range (Hulme, 2011).

Plant invasion; refers to established alien plant that are rapidly extending their range in the new region, usually causing significant harm to biological diversity, ecosystem functioning, socio-economic values and human health in invaded regions (Hulme, 2011).

Invasion stage; refers to colonization of native, localized, spreading and invasive plant species

Native plant; species that have evolved in a given geographical location and were not introduced by humans (Hulme, 2011).

Localised plant; presence of seedlings, saplings, or vegetative propagation, but not necessarily naturalized (Hulme, 2011).

Spreading plant; regenerating species that have recruited new adults, but have dispersed to less than 10 compartment where previously unplanted (Dawson, *et al*; 2008).

Invasive plant; a naturalized/localized species that has spread to 10 or more new compartments and posing threats to native species and other biodiversity (Hulme, 2011).

Dawson number; additional plots where species were found spreading outside the area where they were introduced (Dawson, *et al*; 2008).

Allelopathy; the direct or indirect harmful or beneficial effects of one plant on another through the production of chemical compounds that escape into the environment (Ramgunde and Chaturvedi, 2016).

Appendix 2: Plant species that were used in field and Petri dish experiment in Amani Botanical Garden, Tanzania

S/N	***Alien plants***	**Invasion stages**	**Dawson number**	**Altitude**	**Study 1 (a)**	**Study 1 (b)**	**Study 2**
1	*Maesopsis eminii*	Invasive	47	955	√	√	√
2	*Hura crepitans*	Localised	4	491	√	√	√
3	*Hovenia dulcis*	Spreading	16	888	√	√	√
4	*Ficus elastica*	Localised	0	879	√	√	√
5	*Funtumia africana*	Native	UNK	470	√	√	√
6	*Isoberlinia scheffleri*	Native	UKN	934	√	√	√
7	*Macaranga Capensis*	Native	UNK	960	√	√	√
8	*Syzygium jambos*	Invasive	35	455	√	√	√
9	*Senna occidentalis*	Spreading	1	488	√	√	X
10	*Psidium cattleianum*	Spreading	15	1071	√	√	√
11	*Piper aduncum*	Localized	22	444	√	√	X
12	*Phyllostachys bambusoides*	Invasive	0	604	√	√	√
13	*Neohouzeana dullooa*	Spreading	22	447	√	√	X
14	*Elais guineensis*	Invasive	39	571	√	√	√
15	*Creptomeria japonica*	Locolised	0	1096	√	√	√
16	*Cordia alliodora*	Invasive	30	815	√	√	√
17	*Cinammomum Comphora*	Spreading	10	1014	√	√	X
18	*Cedrela odorata*	Invasive	43	470	√	√	X
19	*Castila elastica*	Invasive	18	618	√	√	X
20	*Arenga pinnata*	Spreading	21	477	√	√	√
21	*Albizia saman*	Localised	22	477	√	√	√
22	*Acer oblongum*	Localised	0	1019	√	√	X

KEY:

√ = was used in the study

X = was not used in the study

Appendix 3: Field sapling assessment collection data sheet

S/N	Name alien /Native selected plant	Scientific name of sapling	Number of individual saplings
1			
2			
3			
4			
5			
6			
7			
8			

Appendix 4: List of plants, growth form and status of species used in Petri dish experiment at ABG in Amani Nature Reserve, Tanzania

S/N	Species Name	Growth form	Family	Status
1	*Maesopsis eminii*	Tree	Rhamnaceae	Highly invasive
2	*Arenga pinnta*	Palm	Arecaceae	Spreading
3	*Hura crepitans*	Tree	Euphobiaceae	Localized
4	*Creptomeria japonica*	Tree (gymnosperms)	Taxodiaceae	Localized
5	*Psidium cattleinum*	Tree	Myrtaceae	Spreading
6	*Cordia alliodora*	Tree	Boraginaceae	Invasive
7	*Phyllostchys bambosoide*	Grass	Poaceae	Invasive
8	*Syzigium jambos*	Tree	Myrtaceae	Spreading
9	*Hovenia dullis*	Tree	Rhamnaceae	Spreading
10	*Abizia saman*	Tree (regumes)	Fabaceae	Localized
11	*Ficus elastic*	Tree	Moraceae	Localized
12	*Elaeis guineensii*	Palm	Arecaceae	Invasive
13	*Isoberlinia scheffleri*	Tree	Fabaceae	Native
14	*Funtumia africana*	Tree	Apocenaceae	Native
15	*Macaranga capensis*	Tree	Euphobiaceae	Native

Appendix 5: Petri dish experiment collection data sheet

S/N	**Petri dish identification number**	**Germination**		**Germination period**	**Remarks**
		Germinated	**Not germinated**		
1					
2					
3					
4					
5					
6					
7					