CHAPTER 1

Introduction

1.1 Historical Background

Primary forest areas around the world have been decreasing. Degradation and destruction of forest has accelerated, mostly caused by human activities, particularly agriculture (Chakravarty, 2012). The highest forest destruction rate arose in temperate forests in Asia, Europe and North America in the early 20th century (FAO, 2012). Deforestation and degradation have been linked to changes in climate patterns and biodiversity loss. To maintain biodiversity and mitigate global climate change, forest restoration of degraded areas has been widely recognized as a solution (Parrotta, 2000).

Conventional methods of forest restoration include production of tree seedlings in nurseries and tree planting (Lamb and Gilmour, 2003; FORRU, 2006). Such conventional methods require construction of tree nurseries and intensive care of small seedlings (FORRU, 2006). Seedlings are transported and planted in target areas (FORRU, 2006; Verdone, 2015). This processes is arduous, time-consuming and expensive (FORRU, 2006). Devising forest restoration methods that are cheap and easy to implement will encourage implementation of more restoration projects, leading to increased forest cover.

Direct seeding is an alternative method for accelerating forest recovery by sowing tree seeds directly into deforested areas (Doust *et al*., 2008). It can result in higher seedling performance in the field, compared with conventional tree-planting (Doust *et al*., 2008; Tunjai, 2005; Tunjai and Elliott, 2012), due to better root system development (Doust *et al*., 2008). Direct seeding has been successful in South Africa, but it has not been widely used in tropical Asia (Lamb, 2005).

Major limitations of direct seeding are seed predation and herbivory of seedlings (Holl, 1998; Doust *et al*., 2008). Studies of direct seeding have largely focused on species selection, based on seed characteristics, for example, thickness of seed coat and seed size (Tunjai and Elliott, 2012). I propose that species selection should take into account likelihood of seed removal by predators etc. Therefore the effects of animals on seed removal, germination success and seedling survival should be tested since currently, information on seed removal and seedling predation for direct seeding programs to guide species selection is limited.

Predators of seeds and seedlings, such as insects and mammals usually interact with plants at different life history stages and in different habitats (Fricke *et al*., 2014). At the seed stage, rodents are the most common predators (Hardwick, 1999, Fricke *et al*., 2014; Wood and Elliott, 2003). Large seeds are lost to rodents, but smaller ones are not because they are less easy to find on the ground (Hardwick, 1999). In some degraded areas, ants are major seed predators (Wood and Elliott, 2003). The effects of seed predation and dispersal on plant population dynamics by seed-harvesting ants are strong (Arnan *et al*., 2012). Finally, at the post-dispersal stage, both vertebrates and invertebrates can be major seed predators.

When seeds become seedlings, they are usually attacked by invertebrates, especially insect pests (Doust *et al*., 2008; Fricke *et al*., 2014). Seedlings have low concentrations of defensive chemicals because of their limited photosynthetic area and root biomass, (Orians *et al*., 2010). In tropical forests, most damage by herbivores occurs on young leaves (Kursar and Coley, 2003). Young leaves are more attractive to herbivores, because they lack structural carbohydrates, which contribute to leaf toughness (Wahungu *et al*., 2002). These insects either kill the seedlings outright or seriously reduce their growth and competitive ability (Barton and Hanley, 2013). Most studies focused on seedlings after the development of true leaves. Therefore, we still lack information of predation of early-stage seedlings that have no true leaves.

This study covered three stages of the seed-to-seedling transition, i) seed, ii) cotyledonous seedling and iii) seedling with true leaves.

Four main research questions were addressed.

1) To what extent do invertebrates (especially insects) and vertebrates (small mammals and birds) remove seeds and reduce germination in a degraded site?
2) How much do animals affect seed removal and seed germination?
3) How much do invertebrates and vertebrates affect seedling survival?
4) What are the potential predators at each stage of the seed-to-seedling transition?

1.2 Hypotheses

1) Seed removal and seedling predation

If vertebrates remove seeds and reduce germination, then excluding them will significantly reduce seed removal and increase germination. If invertebrates remove seeds and reduce germination, then excluding them will significantly reduce seed removal and increase germination. Excluding both invertebrates and vertebrates will result in the lowest seed removal.

2) Effects of animals on seed removal and predation

If vertebrates and invertebrates are equally important seed predators, then percent removal and germination of seeds exposed to vertebrates will not be significantly different compared with seed exposed to invertebrates.

3) Seedling predation and survival

If vertebrates are important seedling predators, then excluding vertebrates from seedlings will significantly reduce seedling mortality. If invertebrates are important seedling predators, then excluding invertebrates from seedlings will significantly reduce seedling mortality.

1.3 Research Objectives

1) To determine the intensity of seed and seedling predation by vertebrates and invertebrates in a degraded site.

2) To quantify the effects of seed predation on seed removal and germination.

3) To quantify the effects of seedling predation on seedling survival and growth.

4) To examine the diversity of potential seed and seedling predators.

1.4 Usefulness of the research

1) This study provides a better understanding of natural enemies that are barriers to forest restoration by the direct seeding.

2) The results can be used to improve tree species selection for direct seeding and protective measures against seed and seedling predation can be devised.

3) This study provides knowledges to help with site preparation and management of direct seeding, both before and after direct sowing.