Darwin Initiative

Half Year Report (due 31 October each year)

PLEASE NOTE: Due to the increased number of reports expected in 2005, we <u>will not be able to confirm receipt of reports</u> but will contact you individually should any questions arise

Project Ref. No.	15/010
Project Title	Buffer Zone Restoration and Development in Knuckles Forest Reserve, Sri Lanka
Country(ies)	Sri Lanka
UK Organisation	University of Aberdeen
Collaborator(s)	University of Peradeniya (SL), Centre for Ecology and Hydrology (UK), Forest Department (SL), IUCN Colombo
Report date	*31 October 2006*
Report No. (HYR 1/2/3/4)	*1*
Project website	*www.abdn.ac.uk/~soi637/KnucklesWebsite/Home.htm*

1. Outline progress over the last 6 months (April – September) against the agreed baseline timetable for the project (if your project has started less than 6 months ago, please report on the period since start up).

We have met the key milestones that were included in the proposal for the first year; these were to 1) appoint project staff and recruit MPhil students, and 2) to hold the stakeholder workshop with project team to agree workplan, define tasks and priorities, establish experimental and sampling designs. More details of these activities is provided below.

1 July 2006 Project Started

July 2006 Balram Dhakal began work as Research Assistant for the project, he was based in Aberdeen until 14 August, at which time he moved to Sri Lanka

16 August 2006 A Stakeholder Workshop in Colombo (Appendix 1) was held where we discussed the conservation, restoration and development issues in Knuckles. We also discussed the project objectives and work plan and received valuable feedback as well as commitments to participate from a variety of participants. There were 28 participants that included delegates from the University of Aberdeen (UK), CEH (UK), University of Peradeniya (Sri Lanka), IUCN Sri Lanka, Open University (Sri Lanka), Finlays (Sri Lanka), Eco-friends (Sri Lanka) and several other local NGOs.

17-20 August 2006 Field visit to Knuckles and planning meetings for project team. General workplan and project objectives agreed.

September 2006 Appointment of MPhil student, Wijethunga Wasala Mudiyansdage Anuradha Madawattae, and Research Assistant,, Bandara Ekanayake, both working on *Pinus* invasion research

October 2006 Appointment of MPhil student, Dona Kaushalya Vajirapani Wijayaweera, and Research Assistant, Anusha Prasangani Indra Kumari Abeyaardana, both working on one of the community-based research projects; Danushka Warnapura Wickramarathna appointed as the MPhil student to work on grassland restoration at the Riverston site.

September and October 2006 Agreement over project design and sampling – the project on *Pinus* invasion has been defined and a proposal approved (Appendix 2). The project on grassland restoration has been discussed and agreed by the project team (Appendix 3) but the candidate that was originally

identified for the research had to withdraw. A replacement candidate was appointed during the week of 23 October. The third MPhil project has been discussed and agreed by the project team but the student are still revising the proposal, the details of which require several site visits and discussions with local communities. Equipment procurement – quotes have been gathered for the purchase of a project vehicle, with the expectation that the transactions will be completed in early November. An office space has been established at U Peradeniya and computing equipment has been procured.

2. Give details of any notable problems or unexpected developments that the project has encountered over the last 6 months. Explain what impact these could have on the project and whether the changes will affect the budget and timetable of project activities.

No problems have been encountered, however, we realised that the GIS Training course was budgeted for the first project year but is actually planned for the second year. We will request a carry-over from the first to the second year of the 10,000 GBP that is dedicated to the course.

Have any of these issues been discussed with the Darwin Secretariat and if so, have changes been made to the original agreement?

The request to carry-over 10,000 pounds was put to the Secretariat on 27 Oct 2006.

Discussed with the DI Secretariat (information given but not yet approved)**:** in Oct/2006

Changes to the project schedule/workplan: no/yes, in…….(month/yr)

3. Are there any other issues you wish to raise relating to the project or to Darwin's management, monitoring, or financial procedures? No.

If you were asked to provide a response to this year's annual report review with your next half year report, please attach your response to this document.

Please note: Any <u>planned</u> modifications to your project schedule/workplan or budget should <u>not</u> be discussed in this report but raised with the Darwin Secretariat directly.

Please send your **completed form by 31 October each year per email** to Eilidh Young, Darwin Initiative M&E Programme. The report should be between 1-2 pages maximum. **<u>Please state your project reference number in the header of your email message.</u>** "Darwin Projects" <Darwin-Projects@ectf-ed.org.uk>

Appendix 1

Stakeholder Workshop on Darwin Initiative Project on Buffer Zone Restoration and Development in the Knuckles Forest Reserve

Date: 16th August 2006
Venue: Hector Kobbekaduwa Agrarian Research & Training Institute, 114, Wijerama Mawatha, Colombo 07.
Objective: Further improvement of the proposed work plan on buffer zone restoration and development through community participation initiatives.

Tentative Workshop Programme

- 9.00-9.20 am: Inauguration ceremony.
- 9.20-9.40 am: 'Conservation management of the Knuckles Forest Reserve'.
  Presentation by a Forest Department speaker.
- 9.40-10.00 am: 'Biogeographical & hydrological importance of the Knuckles and threats to its conservation'.
  Dr. Channa Bambaradeniya, IUCN

10.00 – 10.30 am Tea

- 10.30-10.45 am: 'Rural livelihoods in the Knuckles buffer zone and conservation implications on them'.
  Prof. Anoja Wickramasinghe
- 10.45-11.30 am: 'Vegetation of the Knuckles Region'
  Mr. Sarath Ekanayake, IUCN
  'Molluscs of the Knuckles'.
  Mr. K.B. Ranawana.
  'Amphibians & Reptiles of the Knuckles'.
  Mr. Anslem de Silva and associates;
  'Birds and mammals of the Knuckles:
  Dr. U.K.G.K. Padmalal.
  (10 mins. for each speaker)
- 11.30 -11.45 am: 'Land-use patterns in & around Knuckles & C-sequestration potential'.
  Dr. A.L.S. Dharmaparakrama.
- 11.45 – 12.00 noon: 'Ecological considerations for restoration of degraded lands in the Knuckles region'
  Dr. David Burslem & EU-ASIA link partners.
- 12.00-12.30 pm: General Discussion.

12.30-1.30 pm: Lunch

- 1.30 -1.45 pm: 'Role of Plantation sector on Conservation Management of the Knuckles Region'.
  Mr. James Sandom (James Finlay Group).
- 1.45 - 2.00 pm: 'Vision of the non-resident land-owner community for the buffer zone of the Knuckles region'
  Eco-Friends representative
- 2.00-2.20 pm: 'Darwin Initiative project objectives'.
  Dr. Michelle Pinard, Aberdeen University, UK.
- 2.20-2.40 pm: 'Forest Governance Project in the Knuckles: Objectives & strategies'.
  Prof. Shantha Hennayake, IUCN.
- 2-40-2.50 pm: Introduction to group activities:
  - Conservation issues.
  - Sustainable development issues in buffer zone. (i. rural sector; ii. land owners and plantation sector).
  - Logistic issues. (i. research; ii. training; and iii. nature interpretation).

3.00 -3.20 pm: Tea

- 3.20-5.00 pm: Group activities.
- 5.00-5.30 pm: Plenary & closing remarks.

Group activities

The participants were organised into following four different groups to discuss conservation related issues in Knuckles region.

1) Flora and their habitat conservation related issues
2) Fauna and their habitat conservation related issues
3) Rural communities in buffer zone
4) Private sectors' involvement in buffer zone in relation to providing input to revised management plan.

1) Conservation issues related to flora and their habitats

Fragmentation, forest fire, grazing, land use changes, visitor's pressure, and climate change are the common issues identified in different forest habitats. Almost all types of forests are characterised by the effect of forest fragmentation, fire and land use changes. Fire and grazing related problems are more common in savanna, patana grassland, semi evergreen and dry sub montane forests.

There is a lack of knowledge on the distribution of species and plant communities. The ethno botanical uses of species in Knuckles are not recorded. There is a need of restoration of degraded sites over large scale. However, plant characteristics for restoration are poorly known.

2) Conservation issues related to fauna and their habitats

The common issues identified for the conservation of fauna and their habitats are as follows:

I) Degeneration and deterioration of habitats

- unsustainable cardamom cultivation (depletes the quality of habitats, especially for fauna; reduces the moisture content and water restoration capacity of soil, gradually decreases the depth of humus and leaf litter layer and high soil erosion)
- habitat fragmentation and modification
- Increase in the use of pesticides/weed killers by farmers and commercial plantation sector (This has lead to a reduction in prey species such as insects and birds; the residue may have impacted molluscs and other aquatic organisms)
- man made fire (animal mortality)

II) Impact of invasive and alien species

- Invasive fish such as the guppy (*Poecitia letiution*) pose a problem to endemic forest
- unmanaged domestic animals such as cats, poultry and reptiles, birds and small mammals
- spread of the invasion plant eupatorium has affected ground feeding animals, especially the endemic one such as *Lyriocephalus*, which descends to the ground to feed on earthworms

III) Direct exploitation of species

- road kills (has affected ground dwelling animals, including birds and mammals)
- Illegal poaching (mammals and birds)
- Illegal collection for commercial proposes (i.e. fish, reptiles, spiders, birds etc.)
- over collection for research and education, especially by amateurs
- haphazard/wanton destruction of animals especially spiders

IV) Other issues

- Lack of awareness on unique animals, their habitats and conservation
- Inadequate information on invertebrate species
- Inadequate knowledge and capacity among forest managers to conserve animals and their habitats

3) Issues related to rural communities

There is a lack of trust between government and local communities, which is one of the barriers for community based conservation initiative. Local communities are sceptical with the government forest officials. Local people are excluded from the mainstream of conservation and use of resources and thus they feel the lack of their ownership on local resources. After declaration of conservation area, chena and cardamom cultivation is banned and the alternatives of them to the people who depend on chena and cardamom cultivation are not identified. There could be the possibility of management of non-timber forest products in a new agro forestry system. The mapping of use of forest resources would provide the basis for possible intervention.

4) Issues related to private sector and estates

The possibility for tourism development is to be explored more in Knuckles region. The current trend of uncontrolled tourism is posing a number of environmental problems, mainly due to the lack of awareness. The managed information centre at suitable places and use of mass media like TV would produce extension effects. Additionally the private sector can be involved for the development of infrastructure for tourism development.

There is a need to develop the system for the certification of organic tea and cardamom. The estates can make connection with concerned organisations for the promotion of organic products. Value addition to the local products would give higher benefits at the local level.

Appendix 2

Preliminary Investigation on the Invasion of *Pinus caribaea* as a Potential Threat to the Vegetation of Knuckles Forest Range in Sri Lanka

1. Introduction

The negative impact of alien invasive species (AIS) upon biodiversity has become a global problem. This impact has been more acute in island communities (Clout, 1995). Invasion means that the introduced plants (a plant or propagule has been transported by humans across major geographical barriers) produce reproductive offspring in areas distant from sites of introduction (approximate scales: > 100 m over <5o years for taxa spreading by seeds and other propagules: >6 m/3 years for taxa spreading by roots, rhizomes, stolons or creeping stems) (Richardson *et al.,* 2000). Plants that can tolerate biotic and abiotic environments in general may invade disturbed or semi natural communities. The threat to natural and semi natural ecosystems by invasion of alien invasive plants is a lasting and pervasive threat compared to that of exploitation or pollution (Gunatilleke, 1999).

Recently many workers have investigated on the invasive biota in Sri Lanka (Gunatilleke, 1999; Marambe, 1999; Wijesundara, 1999; Bossard, 1997; Bambaradeniya *et al.*, 1998). Many plant species have been introduced to Sri Lanka during the past 500 years for agro-economic and forestry purposes. Some plant introductions have led to conservation problems by invading adjacent ecosystems. *Annona glabra* Forssk , *Lantana camara* Linnaeus, *Eupatorium riparium* Regel are some classic examples. Since 1952, about 26,000 ha of exotic pine(*Pinus caribaea*) plantations have been established on degraded grassland, tea and scrub lands in Sri Lanka (Muttiah, 1970). However no records are available pine as an invader in Sri Lanka.

Pine forests are the dominant vegetation in many parts of North America, Europe and Asia (Mirov, 1967). Due to their economic importance, many pine species have been introduced to areas well outside their natural range, e.g. southern hemisphere (Versfeld & Van Wilgen, 1986; Richardson *et al.*, 1994 a). In parts of Australia, New Zealand and especially South Africa, invasive pines cause problems for managers of grass lands, water sheds (catchment areas) and protected areas. Because of their large size and tendency to form dense stands, pines have a significant effect on many ecosystem processes (Versfeld & Van Wilgen, 1986; Richardson *et al.*, 1994 a). Reports indicate that pines contribute to an overall reduction in native biodiversity and also cause changes in nutrient cycling in many of the areas it has invaded (Richardson, 1998). Invasive pines can have impacts on humans by reducing the ground water supply level in the area they live in. Rejmanek & Richardson (1995) discuss the ecological significance of life history attributes of pine for invasion. Successful invaders have small seeds, short juvenile periods and short intervals between large seed crops. Additionally, the importance of pines as invaders is usually correlated with the extent and duration of planting (Richardson *et al.*, 1990); this highlights the importance of propagule pressure in determining whether or not a plant will invade (Richardson, 1998). Because seeds and pollen of pines are exceptionally well dispersed and isolated pioneers can give rise to colonies by selfing (Richardson, 1998). In many locations, the invasion of pine species fluctuates in response to altered disturbance regimes or climate change (Richardson and Bond, 1991). Grassland and scrubland are most vulnerable to invasion by pine and forests are generally invaded only after disturbance (Richardson and Rejmanek, 2004). Major vegetation types (more precisely ground-cover categories) can be ranked according to their vulnerability to invasion by pines, provided all other factors being equal, as follows forest< scrubland< grassland< dunes< bare ground (Richardson *et al.*, 1994).

The main pine species introduced to the tropics and subtropics are *P. caribaea* Morelet, *P. elliotii, P. kesiya* Royle, *P. oocrapa, P. patula, P. pinaster, P. radiata and P. taeda* (Richardson, 1998). Among them *P. elliotii, P. patula, P. pinaster and P. radiata* are known to be invasive. Previously Rejmanek & Richardson (1996) categorized *P. caribaea* as non-invasive, but some reports have indicated high level of invasion in New Caledonia (Gargominy *et al.*, 1996) and Hawaii (Smith, 1985). *Pinus caribaea* is native to America and the Caribbean, widely planted throughout America, Asia and Africa. Large scale afforestation of pine began in Sri Lanka in the late 1960s (Tisseverasinghe, 1970) and out of that 60 % are in the mid country (Anon. 1998). About 836 ha of pine plantations are raised in the Matale district, while 4,220 ha have been raised in the Kandy district, most of them are in and around the Knuckles region (Anon., 1998). Degraded grasslands, tea, scrub and largely unusable lands of Knuckles region have been forested with pine (Weerawardane,

2002). Adjacent to these plantations, there are extensive grasslands and forests patches which are disturbed by human activities. Reports indicate that these grasslands and scrublands are frequently disturbed by fire. It has been found that these pines are moderate to high degrees of serotiny (Richardson, 1998) and fire is essential for natural regeneration of *P. caribaea* as well. Consequently, these *P. caribaea* plantations have high possibility to invade adjacent habitats and this can lead to conservation problems. Further more they can cause major impacts to hydrology of the catchments areas by reducing water flows, which affects both the aquatic biota, and water supplies for human populations in the Knuckles region. These problem will become more severe, because there are grasslands which have been already naturally colonized by *P. caribaea* plants in the Revrestone area.

Pines have life history characters that facilitate invasion of certain habitats (Richardson *et al.,* 1990; Richardson and Bond, 1991). Some of these characters are similar to characters shown by pine in Knuckles forest region. Knuckles is a mountain forest reserve situated in the central highland of Sri Lanka. Climatic and geological heterogeneity of the range exhibits various vegetations types and agro-ecological zones. Knuckles region has been divided into five agro-ecological zones, namely WM3b (wet zone, mid country 3b), IM1b (intermediate zone, mid country 1b) IM3 (intermediate zone, mid country 3), IL2 (intermediate zone, low country 2) and IU1 (intermediate zone, up country 1) (Anon., 2003b). Therefore, Knuckles forest reserve comprise a rich composition of fauna and flora, some of them unique to Sri Lanka. There are 1033 flowering plants in Knuckles, 160 (15%) are endemic to Sri Lanka, while about 3% are nationally threatened. Although the Knuckles forest range covers less than 0.5% of the land area in Sri Lanka, it represents almost one third of the island's flowering plant species. With respect to the Knuckles fauna, 12 amphibians are endemic and nationally threatened, among the fishes 8 are endemic and 7 nationally threatened, among the reptiles 23 are endemic and 24 nationally threatened, among the birds 23 are endemic and 20 nationally threatened and among the mammals 4 are endemic and 9 nationally threatened (Bambaradeniya & Ekanayaka, 2003). Besides the Knuckles catchment area contributes about 30% of the water in Victoria, Randenigala and Rantambe reservoirs of the river Mahaweli (Bambaradeniya & Ekanayaka, 2003). Due to these reasons the Government of Sri Lanka declared Knuckles forest area as a conservation forest in 2000. Subsequently, the whole area was declared as a National Man and Biosphere Reserve. The Knuckles area has also been nominated to be declared as an International Man and Biosphere Reserve and a Natural World Heritage Site (Bambaradeniya & Ekanayaka, 2003).

The precious natural and semi natural ecosystems in Knuckles have a potential risk of invasion by *P. caribaea* which had been planted in the Knuckles buffer zone. Further more Richardson (1998) has predicted that *P. caribaea* will probably become a more widespread invader of tropical and sub tropical areas. Taking into consideration all these factors I am planning to investigate the potential of *P. caribaea* invasion in the Knuckles forest reserve. Because evidence from contemporary studies of pine dynamics in the Knuckles is most important to predict the future and current trends in pine invasion for conservation issues.

Hypotheses

- Pine plantations situated in different agro-ecological zones exhibit different rates of invasion.
- Invasion of *Pinus caribaea* depends on propagule pressure of the plantation.
- Different micro habitat types show distinguishable resistance levels to *Pinus caribaea* invasion.

Objective

- Identification and categorization of existing *Pinus caribaea* plantations in the Knuckles area according to different agro-ecological zones.
- Comparative investigation of quantitative parameters (height, density and basal area) of each plantation in the different agro-ecological zones.
- Determination of average cone production of each plantation.
- Investigation of cone production variation in each plantation.
- Determination of the number of naturally established *Pinus caribaea* trees within 100 m on the planting line of the plantation periphery.

- Determination of percentage of different vegetation types that surround the pine plantation within a 100m belt from the boundary of the original plantation.
- Quantification of available *Pinus caribaea* trees (with in 100m from plantation periphery) in each habitat.
- Investigation of age, gbh, height, location and distance (relative to plantation edge) of *Pinus caribaea* trees which have invaded adjacent habitats.

2.Methodology

2.1 Study sites

Ten pine plantations from each agro-ecological zone in the Knuckles region will be selected as the study sites for this investigation.

2.2 Literature and field investigation of existing pine plantations in different agro-ecological zones

- Location, extent, plant spacing, thinning history and planting date of each of the existing *Pinus caribaea* plantations will be recorded from already available information in the Forest and Survey Departments.
- Further detail of each plantation will be collected by asking questions from nearest villagers e.g. fire history, seed production.
- Each plantation will be numbered and categorized according to their agro-ecological zones.
- Point Centered Quarter Method (Cottam *et al.,* 1953) will be used to obtain quantitative parameters (height, density and basal area) of the structure of each plantation. Five randomly selected points will be used to apply the above method in the each plantation.
- Comparison study will be done between plantations in each eco zone and among plantation in different zones, especially with regard to pine invasion.

2.3 Investigation of cone production of each plantation

- Ten *Pinus caribaea* trees (randomly selected) will be taken from each plantation to measure average cone production quantity.
- Thirty pine cones will be collected from each plantation, length, width and mass will be recorded. Cones will be dissected and the number of seeds within each cone estimated.
- Transect sampling method will be used to determine cone production variation in each plantation (cone quantity of five trees on the edge, five trees at 10 m inside from the edge and up to 60 m at 10 m intervals would be taken to compare cone production at these different sites).
- At the periphery of the plantation along a line transect of 100 m on the planting line the number of *P. caribaea trees* will be recorded.
- The relationship between propagule pressure and invasion among plantation will be investigated, using the collected data.

2.4 Investigation and quantification of available *Pinus caribaea* trees in adjacent habitats on the edge

- Length of the perimeter of the selected pine plantation, mean elevation and elevation range of the plantation, land gradient (slope) and the percentage of different vegetation types that surround the pine plantation within a 100 m belt will be determined.
- The nature of the ground-cover category of each habitat surrounding the pine plantation within the 100 m belt will be recorded.
- The number of *Pinus caribaea* trees in each habitat (100 m out side from the plantation edge) will be counted. Then ground-cover categories will be ranked according to their vulnerability to invasion by pines.
- Girth at breast height, tree height, age, location and distance (relative to parent plants) of the invading pines will be measured. The criteria to decide weather a species is invasive, clear evidence is required that it regenerates naturally and the seedlings have been recruited more than 100m away from parent plants (Richardson *et al.,* 2000).

- Above data will be used to obtain how invasion take place in surrounding habitats of each plantation.

Results of the above study will be used to determine whether different eco zones, habitats and propagule pressure influence the pine invasion in combination or separately in the Knuckles forest region.

WORK PLAN

Activities	Oct- Dec 2006	Jan-Apri 2007	May-Aug 2007	Sept.-Dec 2007	Jan-Apri 2008	May-Sep 2008
Literature survey						
Field experiments						
Site selection						
Investigation of existing plantations						
Investigation and quantification of *Pinus carib* trees in each habitat						
Investigation of cone producing variation and average cone production number of the each plantation						
Thesis writing						

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Appendix 3

Draft research proposal for grassland restoration in Knuckles

Introduction

Large areas of former lower montane rain forest in the Knuckles Forest Reserve (KFR) have been cleared and converted into perennial crops, largely plantations of tea, over the last 200 years. In areas where tea has been uneconomic, either because of fluctuations in price or because the climate for tea production is marginal, the plantations may be abandoned, or otherwise converted into alternative land uses such as *Pinus* plantations. Unmanaged plantations are susceptible to increased incidence of fire during drier times of year, and to the invasion of exotic grasses such as *Cymbopogon* (Lemon Grass). Over time these sites revert to species-poor communities heavily dominated by the *Cymbopogon*, rather than to forest communities analogous to those that formed the original vegetation on these sites. The fires originate from deliberate ignition events associated with local communities living in the KFR adjacent to the grassland areas. These local communities ignite the grasslands for various reasons, but particularly to provide improved forage for their buffaloes. We have identified sites in the KFR buffer zone where succession has become arrested at the grassland stage even despite the close proximity of patches of remnant lower montane rain forest that could provide a source of propagules for forest regeneration. The aims of our research is to determine the causes of arrested succession and to develop practical strategies to facilitate restoration of species-rich lower montane rain forest. We will achieve this by testing the following specific hypotheses:

1. Dispersal limitation of forest tree species reduces propagule arrival in grasslands.
2. Poor seed survival in grassland prevents the build up of a substantial seed bank of forest tree species.
3. Fire and grazing reduce tree seedling emergence and survival of emergents in grasslands.
4. Competition with *Cymbopogon* reduces growth and survival of established tree seedlings.

Design and Methods

Separate studies have been designed to address the four hypotheses identified above using blocks from the forest/grassland mosaic in the Riverston area of the KFR buffer zone. Four blocks were selected to include a remnant patch of lower montane rain forest adjacent to a substantial (c. 5 ha) area of grassland dominated by *Cymbopogon*. The blocks comprised contiguous 40 x 40 m plots in the grassland and forest with their common boundary forming the forest/grassland edge, which occurs abruptly, i.e. over a distance of < 10 m, in this part of the KFR. The grassland plots were surrounded by a 5 m fire belt in which all vegetation is regularly cut to ground level to prevent accidental ignition of experiments within the plots. The following four studies were initiated within each of the blocks.

1. Dispersal limitation. Seed traps are located at the forest/grassland edge and at 10, 20 and 40 m into the grassland and forest communities along four transects within each block (7 locations x 4 transects x 4 blocks = 112 seed traps). The seed trap contents are emptied once each fortnight, sorted into seeds and fruits vs other material (such as leaf litter), and the seeds and fruits are identified to the lowest possible taxonomic level and counted. Reference collections of the seed and fruits of the local flora have been made and archived at the study site and the University of Peradeniya. The results will allow us to quantify the extent to which forest tree species are being dispersed into adjacent grasslands, and to estimate the spatial scale of dispersal events.

2. Seed bank sampling. Adjacent to the location of each seed traps, one soil sample was extracted during each of the wet and dry seasons, divided into depth slices (0-5 and 5-10 cm), spread onto a layer of sterilized in a shadehouse and observed daily for up to four months. Newly emerged seedlings were identified to the lowest possible taxonomic level and counted. As an aid to identification, representative seedlings of each taxon were transplanted into pots of soil and allowed to grown on until their identity could be verified. Photographs and herbarium specimens were also compiled and archived on the project website and at the University of Peradeniya, respectively. These results will allow us to determine the population size of buried seeds of forest tree species during wet and dry seasons and in the forest and grassland communities.

3. Effects of fire and grazing on seedling emergence. Seedling quadrats (2 x 1 m) were located in groups of three at the forest/grassland edge and at distances of 10, 20 and 40 m in the grassland, and singly at similar distances into the forest, along four transects within each block. In the grassland sites the three quadrats were

randomly allocated to treatments imposing cutting (all vegetation cut to ground level every two weeks), tilling (soil turned over to 10 cm depth two times a year) and no manipulation (control), and one group of three quadrats at each distance was allocated at random to a factorial combination of burn (annual controlled burn during the dry season) or not and absence (quadrats surrounded by a 1.5 m high fence to exclude vertebrate herbivores and buffaloes) and presence (no exclosure) of grazing. In the forest the single quadrat per distance represented a 'no manipulation' control without burning (which does not occur in the forest) but with grazing (no exclosure). All quadrats were censused once per fortnight for the emergence of new seedlings of woody plants, which were permanently tagged, identified to the lowest possible taxonomic level and monitored until death. Identification was aided using the procedures outlined above. This experiment will allow us to test the roles of above-ground and below-ground competition on seedling establishment in the presence and absence of fire and grazing, and to compare seedling emergence between forest and grassland communities until 'natural' conditions.

4. Effects of root competition on the growth and survival of tree seedlings in grassland. Seedlings of four tree species (two pioneer, two non-pioneer) were obtained from pre-existing cohorts in natural forest patches and transferred to pots of forest soil in a sheltered nursery site to allow them to acclimate. They were then transferred to planting sites in the grassland and forest habitats and censused for seedling growth and survival over time. The experiment comprised a factorial combination of the absence (seedlings enclosed within mire mesh cages) or presence (no exclosures) of grazing and the absence (seedlings planted into polythene tubes preventing ingrowth of grass roots) or presence (no tubes) of root competition. This experiment will allow us to determine the relative importance of grazing and root competition in grassland and forest communities for species representative of the extreme of tree life histories in terms of successional status.

Brief summary of results to date

1. **Dispersal limitation** is very marked. No dispersal of tree seeds was observed at a distance of 40 m into grassland sites over a one year period, and inputs of tree seeds to traps closer to the forest edge were very low.
2. **Seed bank densities** of tree seeds in grassland sites is very low.
3. **Seedling emergence** is enhanced by elimination of below-ground competition and reduction in burning.
4. **Tree seedling growth and survival** are enhanced by reduction in root competition from grasses.