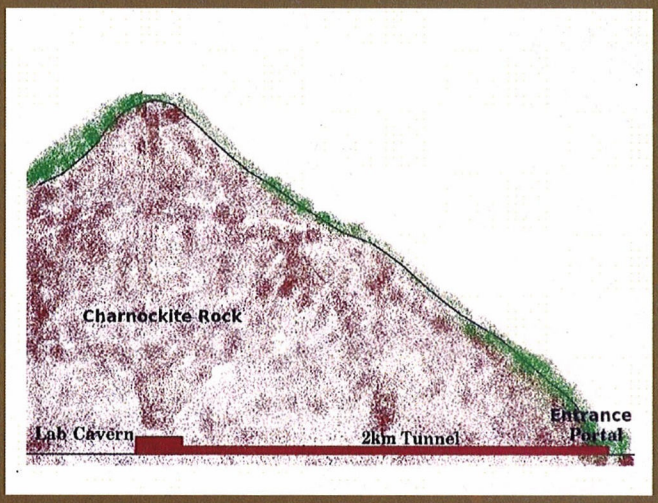
RAPID EIA OF THE INDIA - BASED NEUTRINO OBSERVATORY PROJECT, BODI WEST HILLS, THENI, TAMIL NADU



Report submitted to
Institute of Mathematical Sciences, Chennai
by

PA Azeez, PP Nikhil Raj and M Murugesan

SACON

Sàlim Ali Centre for Ornithology and Natural History

Coimbatore, Tamil Nadu
November 2010

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1 EXECUTIVE SUMMARY

- The Institute of Mathematical Sciences (IMSc), Chennai requested M/s Sálim Ali Centre for Ornithology and Natural History (SACON) to conduct an Ecological Impact Assessment study of the proposed India-based Neutrinos Observatory (INO) project site at Pottipuram Village, Uthamapalayam Taluk, and Theni district of Tamil Nadu district.
- The present study explored the biological diversity of the project area and its surrounding environment. The study focused on a circular area falling within 5 km radial distance from the site of the portal to the underground laboratories.
- In all, 517 species of plants and 232 species of vertebrates (14 species of amphibians, 27 reptiles, 137 birds and 54 mammals) and 59 species of butterflies were recorded from the study area, a circle of 5 km radius. Several endemic (endemic to the Peninsular India and Western Ghats) and endangered flora and fauna are found in the study area. Nevertheless, none of these species are limited to the study area and are widely distributed elsewhere.
- Most of the construction work of the proposed project will be carried out deep underneath the earth surface. The activities such as blasting, muck dumping and clearing the vegetation will have impacts on the local environment. However, noting that wildlife is rarely reported in the Portal area, the impacts of the actvities on them will be effectively negligible. Proper work plan, plans for debris and waste disposal, restricting blasting activities to the optimum, controlled vehicular activities and limiting the number of workers residing in the project site may help to reduce the impacts.
- Infrastructure development for science and technology is vital for a country like India. In this direction, the proposed project, the single most expensive and comprehensive project towards cutting edge science and one of global importance would be a milestone. Nevertheless, during the construction phase, the project is likely to have certain impacts on the environment. However, these impacts are low considering the ecological setup of the area where the project is going to be located. By adopting proper planning and management measures these impacts could be reduced to a considerable extend. During the operation phase, the impact of the project on environment is negligible, except in situations such as certain untoward incident or disasters.

2 INTRODUCTION

Neutrinos are tiny, neutral, elementary particles, which interact with matter via the weak force. The weakness of this force gives neutrinos the property that matter is almost transparent to them. The Sun, and all other stars, produces neutrinos copiously from nuclear fusion and decay processes within their core. Since they rarely interact, these neutrinos pass through the sun, and even the earth, unhindered.

There are several other natural sources of neutrinos including exploding stars (supernovae), relic neutrinos (from the birth of the universe), natural radioactivity, and cosmic ray interactions in the atmosphere of the earth. For example, the sun produces over two hundred trillion trillion trillion neutrinos every second, and a supernova blast can unleash 1000 times more neutrinos, in a matter of seconds, than our sun will produce in its 10-billion year lifetime. Billions of neutrinos stream through our body every second, yet only one or two of the higher energy neutrinos will interact with us in a lifetime of decades.

It was Wolfgang Pauli, who proposed the neutrino as an elementary particle in 1931; but it took another 26 years for it to be actually detected. In 1956, Reines and Cowan found evidence of neutrino interactions by monitoring a volume of cadmium chloride with scintillating liquid placed near a nuclear reactor. Reines was jointly awarded the Nobel Prize in Physics in 1995 for this revolutionary work. At least three types or flavours of neutrinos and their anti-particles, called anti-neutrinos, are known to exist in nature. They have a tiny mass whose value is still not known. Moreover, they exhibit a quantum-mechanical phenomenon in which one type of neutrino oscillates into another as it propagates in space; this phenomenon called neutrino oscillation has generated immense excitement in the particle physics community.

From recent experiments, we know that the mass of the neutrino is non-vanishing, but we are unsure how large the masses of the three individual neutrino types are because of difficulty in detecting neutrinos. This is important because neutrinos are by far the most numerous of all the particles in the universe (other than photons of light) and so even a tiny mass for the neutrinos can enable them to effect the evolution of the universe through their gravitational effects. Other recent astrophysical measurements provide valuable information on the evolution of the universe and it is further crucial to seek complementary information by direct determinations of the masses of neutrinos and their other properties. In a sense, neutrinos hold the key to several

important and fundamental questions on the origin of the universe and the energy production in stars. We have some partial answers but many details are yet to be revealed from future experiments.

Down to earth, an important possible application of neutrinos is in the area of neutrino tomography of the earth, the detailed investigation of the structure of the earth from its core up wards. This may be possible in the near future with neutrinos since they are the only particles, which can probe the deep interiors of the Earth.

Neutrinos, as mentioned before, are notoriously difficult to detect in a laboratory because of their extremely weak interaction with matter. The background from cosmic rays (which interact much more readily than neutrinos) and presence of natural radioactivity on the surface will make it almost impossible to detect them on the surface of the Earth. This is the reason why most neutrino observatories are located deep inside the Earth's surface. The overburden provided by the earth matter is transparent to neutrinos whereas most of the background from cosmic rays is substantially filtered out depending on the depth at which the detector is located.

One of the earliest laboratories created to detect neutrinos underground in the world was located more than 2000 m deep at the Kolar Gold Field (KGF) mines in India. In a pioneering effort, the first atmospheric neutrinos were detected at this laboratory in 1965. This laboratory has been closed due to the closure of the gold mines. Most underground laboratories around the world are located at a depth of a kilometre or more; either in a mine or deep in a tunnel under a mountain. As of now, there are four major laboratories around the world: in Sudbury in Canada, Kamioka in Japan, under the Gran Sasso Mountains in Italy and in Soudan mines in the USA. Several others are planned including the India-based Neutrino Observatory (INO), which is an attempt to take forward the pioneering studies on neutrinos at KGF.

A typical underground neutrino laboratory requires a rock cover of more than 1000 metres in all directions. Under such conditions, the stresses from the rock are very high and therefore for safety of the laboratory it is extremely important to situate the laboratory under stable, compact rock as is found in the mountains of Tamil Nadu. Advance information on rock conditions is an added advantage to any site. Seismic stability is yet another important criterion; it is a crucial ingredient for the design and stability of the underground detector as well as all surface facilities at the site, especially for the life span of such a laboratory (50-100 years). Generally, low rainfall area of about 75 to 100 cm per annum is required for operating detectors, which are sensitive to humidity.

The INO has been conceived on a scale that no other basic sciences project in India so far has attempted. The MoU signed by seven institutions supported by the Government of India, that brought the Neutrino Collaboration Group into existence, is the first of its kind. Currently the group has members from nearly 25 universities and research institutions; a testimony to the enthusiasm and collaborative spirit of the scientific community in India.

In the first phase of its operation a magnetised iron calorimeter detector, weighing about 50,000 tons, will be used for studying neutrinos produced from cosmic rays in earth's atmosphere. The aim is to make precision measurements of the parameters related to neutrino oscillations. An exciting possibility is to determine the ordering of the neutrino masses which is not known at present and is one of the fundamental open questions in neutrino physics. Because of its ability to distinguish, the positive and negative muons produced in neutrino interactions, this detector in principle can settle this question.

This detector can also be used as the far-detector of a long-base-line (6000 to 11500 km) neutrino experiment using the neutrino beam from a neutrino factory in Japan, Europe or USA. The neutrinos that will be produced in a future accelerator facility are beamed towards the detectors situated in a different part of the Earth. This is envisaged as the second phase of the INO activity, and is a long-term goal, since neutrino factories are yet to become a reality. However, there is considerable interest in this possibility not only for its rich physics potential but also because the proposed detector at INO will be capable of charge identification, which is crucial for this mode of operation.

The INO will have an impact on the emerging high-energy physics scenario in the country. People trained at INO will not only participate in the research undertaken here but also have the expertise to contribute to other high energy and nuclear physics projects around the world. Over the long term, the INO is expected to develop into a world-class underground science laboratory working across many fields like physics, biology, geology and allied engineering fields.

Initially the INO was proposed to be located in a village called Singara near Masinagudi town in Nilgiris district of Tamil Nadu. Though the site at Singara is the best site for locating INO especially in terms of the locational and geological setting and access to certain infrastructure facilities, the site was not cleared by the Tamil Nadu forest department and therefore by the Ministry of Environment and Forest of the Government of India. The proximity of Singara to the Mudumalai Wildlife Sanctuary, which has since been declared as a Project Tiger area, the

frequency of animals crossing the road to the INO site, and the site located in a region being declared as the buffer zone of the Tiger project area, were important considerations in this decision.

The INO collaboration is now considering a site in Bodi West Hills (BWH) region near Pottipuram village in Theni district for locating the project. Detailed studies of this site from engineering, geological and environmental perspectives are going on now. Upon the request from the Institute of Mathematical Sciences (IMSc, Chennai), co-ordinating the establishment of the INO, Sálim Ali Centre for Ornithology and Natural History (SACON) carried out a rapid ecological assessment of the location, while different organisations are looking into other issues related to the site.

3 THE PROJECT

3.1 LOCATION

The Pottipuram village, located near Thevaram, falls under the Uthamapalayam Taluk, Theni district of Tamil Nadu. The newly proposed site for the INO (77°17'5.32" E 9°56'46.20" N) is located near Pudukkottai in Pottipuram village. The project site is abutted on the western side by the high ranges (Figure 1) of the southern Western Ghats. The major townships around the site are Bodinayakkanur on the north about 18 km away, Theni on the north-eastern side about 35km away, Chinnamannur situated (~25km away) on the south-eastern side and Kambam (~21km away) on the southern side. Pottipuram village is connected to the nearby townships by road. A cart road leads up to the INO portal site. Nearest railhead is at Bodinayakkanur.

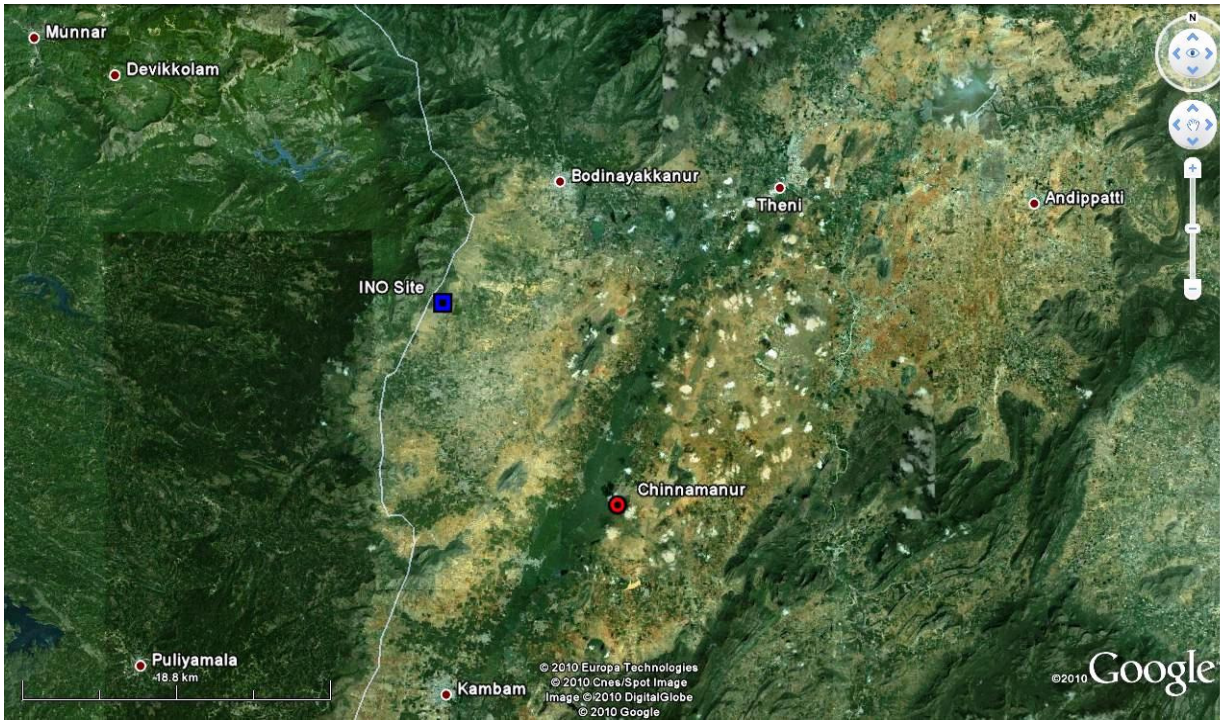

Figure 1: Location of the proposed site in the Bodi-west forest area, Theni district

3.2 MAJOR COMPONENTS

A brief of the project is given in the table 1. The major components of the project consists of the main cavern (132 m x 26 m x 32.6 m,Figure 2) housing the experimental set up, a second cavern (55 m x12.5 m x 8.6 m) for the control and utility equipment, and inter-connecting auxiliary and adit tunnels for access and safety. The smaller cavern may also accommodate smaller experiments. There is also a proposal to build a third, small cavern, for future experiments. The portal of the tunnel leading to the caverns will be located nearby Pottipuram Veerappasamy temple while the caverns will be built about 1 km underneath the high hillock of Ambarasakaradu.

The large cavern can accommodate two Iron Calorimeter (ICAL) detectors (Appendix 1). The ICAL detector is a static device that observes the neutrino-sky, in the manner of a telescope. The detector set-up essentially consists of glass Reactive Plate Chamber (RPC) detector elements sandwiched between stacks of magnetized steel plates. The magnets of the detector will be water cooled. The neutrinos entering the detector, while passing through the steel plates generates charged particles called muons, the tracks of which will be detected by the active detector elements (RPCs). The RPC is a thin flat glass chamber with metallic coating. The glass chamber is filled with a gas mixture of about 95.5 % Freon (R 134a), 4.2% Isobutane and 0.3 % SF6. The total volume of the gas circulating in the ICAL detector will be around 200 m^3. As per the INO sources, the gas mixture will be in a closed loop and recycled several times before it is let out after diluting with fresh air.

Table 1: Brief project information of INO at Bodinaykkanur		
1	Location	Pottipuram Village, Theni District, 35km from Theni town
2	Under ground facility	Laboratory caverns and tunnels = 25360m^2 (area) i) Cavern 1 = 132m x 26m x 32.6m = 111883 m^3 (vol) ii) Cavern 2 = 55m x 12.5m x 8.6 m = 5912.5 m^3 (vol) iii) Cavern 3 = 40m x 20m x 10 m = 8000 m^3 (vol) iv) Access tunnel = 1750m long x 7.5m diameter
3	Over ground facility	Utility building, administrative building/ surface lab, assembly shop, guest house/hostel & housing (up to 1+2 floors) – 12625 m^2
4	Expected cost	1200 /- Crores (Preliminary estimate including detectors)
Source: INO, 2010		

As mentioned earlier, the caverns and the tunnel (Figure 2) will be located underneath (Figure 3) the Bodi-west Reserve Forest (RF) area. The 1.75 km long horizontal tunnel cutting through the charnockite rock, sloping down slightly with a gradient of 1:13.5 beneath up to the Kerala state border leads to the laboratory. The caverns are located with in Tamil Nadu state. Vertically and radially from the laboratory cavern the rock cover will be more than 1000m. The portal will be cored out at 422-435 above msl out side the RF boundary (INO, 2010).

The over ground facilities of the project (Table 2) include surface laboratory, administrative building and residential facilities for the workers. The existing 1.8 km cart track will be converted to a 10 m wide blacktop road to reach the portal and a new internal road stretching 1500 m will be built within the INO site. The 8 km length of the present village road will also be modified by strengthening /widening. A new bypass road at Rasingapuram village will be constructed for transportation of materials to the site (Figure 4).

3.2.1 Water requirements

The project requires about 40KLD water during construction phase. This will be arranged through tankers. About 340 KLD water is required during the operation of the project. This will be sourced from the river Mullaiperiyar through TWAD board. To minimize the water requirment closed cycle cooling water system will be adopted and the serviced water is conceived to be reused for gardening.

3.2.2 Energy requirements

A peak demand of 3 MW is estimated as the total energy requirement for the project. Power will be sourced for the project via independent dedicated feeders. Twin circuit 110KV over head transmission lines tapped from Periyar –Theni TNEB Feeder will supply power to the 110KV substation at INO site.

Table 2: Surface facilities proposed for INO at Pottipuram		
Items		***Dimensions***
1	Area under surface facilities	23 ha
2	Total built up area	12625 m^2
3	Roads	3.3 km
4	Bridges	10 m wide
5	Residence for	20 families
6	Hostel / guest house for	40 members
Source: INO, 2010		

3.2.3Man power requirement

As per the INO, 20 families will be residing permanently in the proposed project site during its operational phase. Approximately 80 people will be resident in the area (Table 3). The floating population during INO operation will be around 40 including scientists, students, other officials and occasional visitors. During the construction phase of the project much larger will be the work force requirements (Table 4). In all, 110 men (contractor workers and departmental staff) will be working at the site on daily basis during the construction.

Table 3. Resident population during the Operation phase	
Personnel	***Number***
Scientists	6
Auxiliary staff	14
Family members	60
Total	80
Source: INO 2010	

Table 4. Personnel involved in INO project and the resident population during Construction phase							
Year	***Contract Labour***			***Departmental Staff***			
	Skilled	***Semi Skilled***	***Unskilled***	***Engineers***	***Scientists***	***Family members***	***Total***
1	20	20	50	10	10	220	330
2	20	20	50	10	10	220	330
3	15	15	40	10	10	180	260
4	20	10	-	5	10	60	105
5	20	05	-	5	10	50	90
Source: INO 2010							

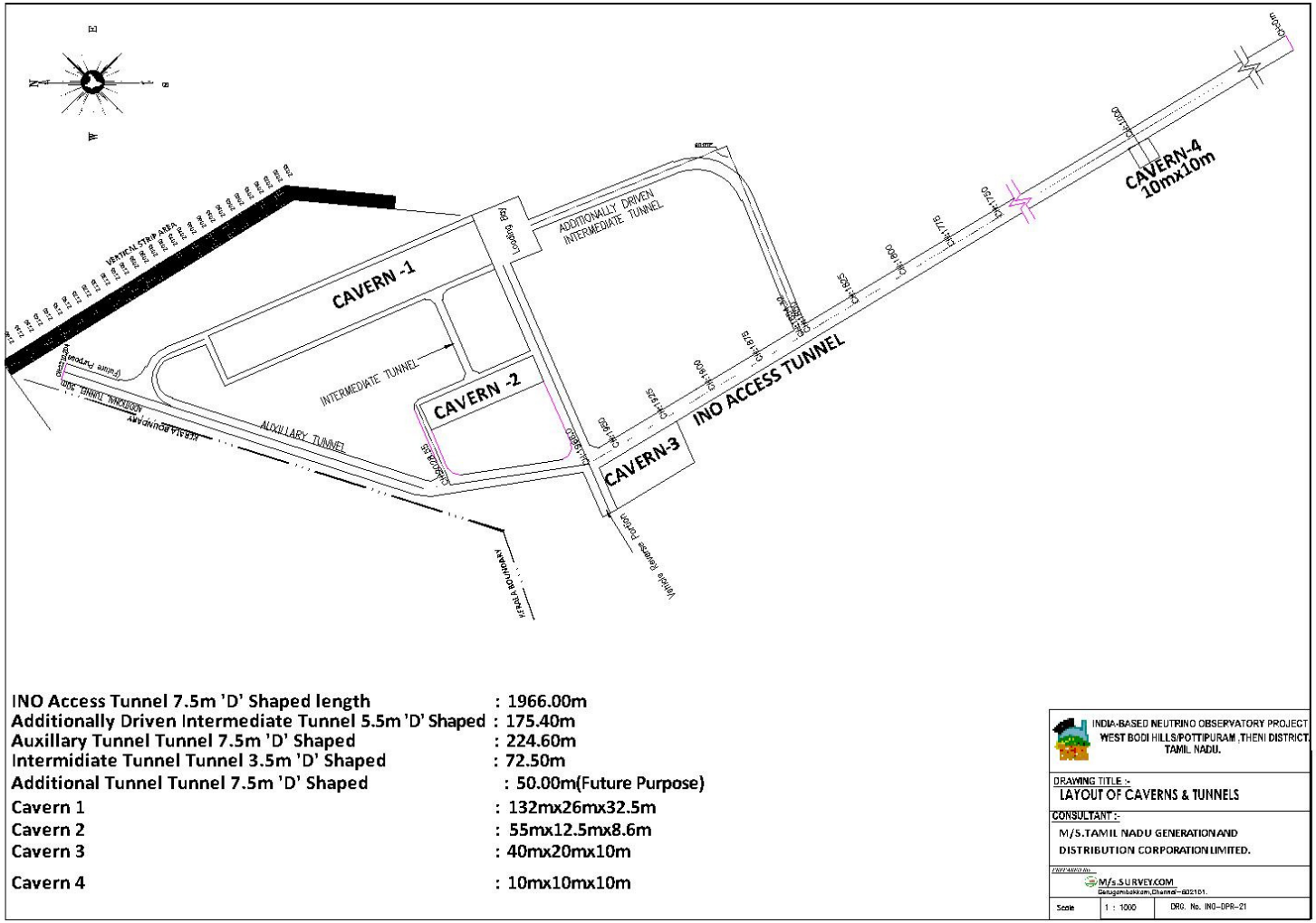

Figure 2: Layout of the proposed caverns and the tunnels. The vertical overburden is more than 1250 metres above the main cavern.

3.2.4 Construction technology and execution

The major construction works required for the proposed INO project at Bodinayakanur and the technology adopted for the purpose will be as follows.

- Excavation of the access tunnel, adits and the cavern for laboratory
- Concrete lining of the tunnel and caverns
- Mobilizing materials and equipments for the laboratory
- Establishment of underground laboratory and related facilities
- Building residential quarters and administrative facilities

All the above activities except the last one are to occur underground. The access tunnel will open to the surface through a portal. Once the portal is formed, tunnelling will be carried out by core drilling and blasting. Other associated shafts and underground caverns will be excavated in appropriate sequence one after the other through the access tunnel. Concreting works in the tunnel will be carried out while the excavation is being completed.

According to the INO sources, tunnel would be excavated using conventional drilling technology. Blasting pattern requiring minimum charge and yielding maximum pull will be designed based on the nature and quality of rock mass and size of excavation. All tunnels, except construction adits, will be excavated first followed by benching. The sequence of tunnelling operation is given in the Table 5 below. The constructions will involve several machineries (Table 6). It is expected that the construction would be completed in four years. The installation of the ICAL experimental set up will take another one year for the first module. The remaining two modules will be built over another two years time.

Table 5: Sequence of tunneling	
1	Surveying and marking of the area to be excavated
2	Drilling of holes as per blasting pattern design
3	Loading of explosives
4	Blasting
5	Defuming
6	Scaling
7	Supporting (Shotcreting, Rock bolting, etc.)
8	Drilling drainage holes wherever seepage of water encountered
9	Concrete lining and grouting

Table 6. Major construction machinery likely to be used for INO construcion		
Drill jumbos - 4	Jack hammers - 10	Hand winches- 2
Air compressors-3	Road rollers - 1	Rock bolters- 5
Mobile cranes- 3	Gas welding units- 3	Jeep/van- 4
Tippers- 10	Dewatering pumps with motors-10	Excavators/ Loaders-5
Lorries- 2	Pneumatic rock drills- 3	

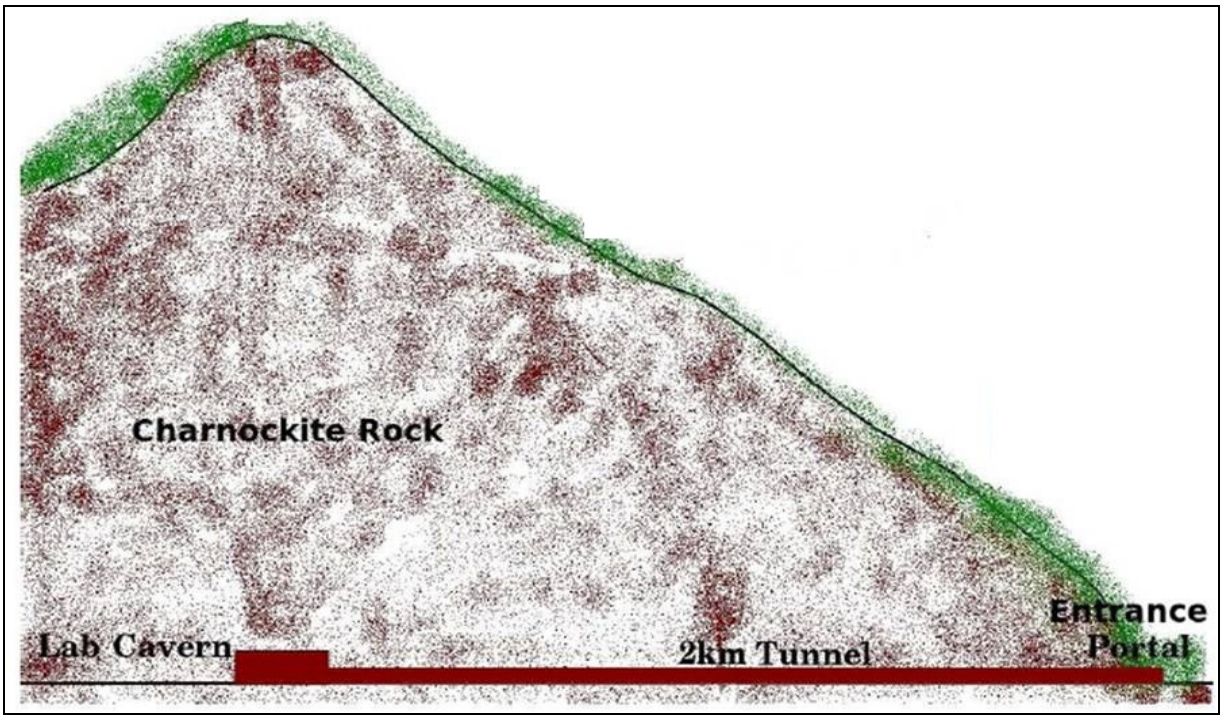

Figure 3: Cross-sectional diagrammatic representation of INO underground facilities

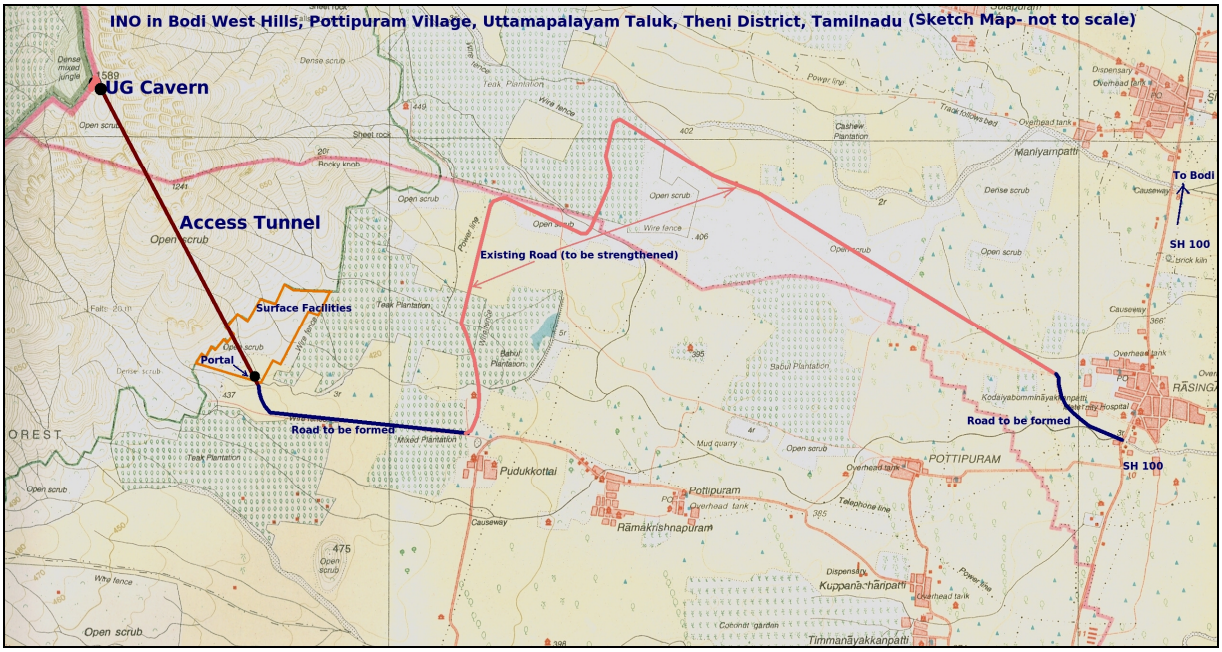

Figure 4: Location of road and surface facilities at the proposed INO Site

4 ECOLOGICAL ASSESSMENT OF THE ENVIRONS OF THE PROJECT

Ecological Assessment is an activity that results in documenting the ecological status of an area, species inhabiting the area, their ecological / econservational requirements etc. It is a fundamental and important component of Ecological Impact Assessment. It essentially generates baseline data and information on an ecosystem or an area. Environmental / Ecological Impact Assessment is a process to be conducted prior to executing a large-scale project. All such projects are likely to have impacts on the environment; more or less coextensive to factors such as the magnitude of the project, the activities involved, resources utilized, and wastes, emissions and effluents. Ecological Impact Assessment is a method of identifying, quantifying and evaluating the potential impact of defined action on ecosystems or their components (Treweek, 1999). During the process of the assessment scientific information about the ecological makeup of the natural system in and around the project location has to be collected. A scientific documentation of the baseline data is vital to develop a general perception about the project and its impacts. This is necessary to help developing a long term and strategy for management of the area specifically the habitats by identifying the means to mitigate the possible impacts of the activities proposed to be undertaken in the area. This would in turn help to bring back the local environmental setup and ecological goods and services more or less close to its original state, and facilitate decision-making on the project basically on evaluating the trade-offs between the loss of environmental quality, environmental services and the goods and services offered by the project.

4.1 SCOPE AND OBJECTIVE

The scope of the present study is restricted to the assessment of the proposed INO site at Bodi-west forest area (BWH) in terms of its biological and ecological set-ups.

The major objectives of the study, within the frame of the scope, include the following.

- Assess and document the flora in the project location and its environs
- Assess and document the fauna in the project location and its environs
- Examine the probable impacts arising from the execution of the project on biological and ecological environs, and
- Develop an Ecological Management Plan (EMP) for mitigating the impacts, if any.

4.2 METHODOLOGY

4.2.1 Hydrometeorology and physiography

Data related to the hydrometeorology, wind patterns and physiography were obtained from public domain.

4.2.2 Ecological assessment

To delineate and mark the study area, an area falling within 5 km radial distance from the portal location, Survey of India (SOI) topographic map series, 58 G/1 and G/5 were used. Extensive field surveys were conducted from January to June 2010, adopting standard methods to identify and document the ecological / biological components. However, in view of the western part of the study area falling under the jurisdiction of the Kerala forest department, and the permission to study the protected areas were obtained by the INO only from the Tamil Nadu forest department, and since no surface activity / construction is envisaged in that area we have relied mostly on the available secondary data to furnish the ecological set-up of the Kerala part of the study area. No field survey, specifically intended to collect information in view of the present project, was carried out in the Kerala part.

At first, a pilot survey was carried out in and around the 5 km radial distance from the proposed portal to develop a feel of the area and to identify intensive sampling sites. Thus we selected four representative areas (A, B, C and D sections, Figure 5) for intensive studies. The portal is situated in the B Section.

To study the flora of the study area in general and to estimate the tree density in particular, quadrats of 25 x 25 m size were laid adoting more or less the strategy of cluster sampling. In total 35 such quadrats were laid to represent all the vegetation types during the present study. The Girth at Breast Height (GBH) of trees (having GBH > 20cm) occurring in the 25 x 25 m plot were recorded. In the middle of each such quadrat, a 5 x 5 m quadrat was laid to estimate shrub density. Similarly, a 1 x 1 m quadrat was laid within the 5 x 5 m quadrat to record the herbaceous species. All the herbaceous species within the 1 x 1 m quadrat were counted and recorded. All species encountered during the surveys, whether in or out of the qaudrats, were also recorded. Information on flora available in previous works was also included with appropriate citations. Taxonomic identification of the species encountered in the field was done consulting the flora of Hooker (1872-97), Gamble (1957 and Matthew, (1999). Specimens of unidentified plants were preserved in 10% formaldehyde and brought to the Botanical Survey of India, Coimbatore, for further identification by experts. The nomenclature followed in the present study was based on the Flora of Tamil Nadu Series 1: Analysis vols. 1-3 (1983-1989). Endemic status of certain species was checked with the help of relevant literatures (Ahmedullah and Nayar, 1987; Nayar, 1996).

The vegetation data were analyzed to obtain the quantitative structure and composition of plant communities. Synthetic characters of the forest vegetation such as species richness and diversity of species in the stands were estimated (table 7). The vegetation data were tabulated as frequency, density, abundance, relative frequency, relative density, relative abundance, relative dominance, IVI and composition of plant communities, following Curtis and McIntosh (1950) and Philips (1959).

The survey of the fauna in the study area was conducted following widely used and standard methods (Table 8). Visual encounter survey method (search) was adopted for amphibians and reptiles whereas opportunistic observations and random walk method were followed for birds (Bibby, et al., 1992). To survey mammals, tracks and signs, and visual encounter survey were

used. Species were also identified by indirect evidences such as pugmarks, calls, signs and scats (Bang, et al., 1972; Heyer, et al., 1994).

Table 7: Estimating quantitative structure and composition of plant communities	
Parameters	***Formula adopted***
%Frequency	(No. of quadrats in which a species occurred/ Total no. of quadrats studied) × 100
Abundance	Total number of individuals of the species/ No. of quadrats in which the species occurred
Density	Total number of individuals of a given species/ Total no. of quadrats examined
Relative density	No. of individuals/ Number of individuals of all species
Relative dominance	Total basal area/ Total basal area of all species
Relative frequency	Number of quadrats occurring/ Total no. of quadrats
Basal area	(GBH) 2 / 4π
Relative Basal area	(Total basal area of Individuals/ Total basal area of all species) ×100
IVI	Relative density + Relative dominance + Relative frequency

Table 8: Sampling techniques used for faunal study	
Taxa	***Sampling Methods***
Amphibians	Visual encounter survey (search)
Reptiles	Visual encounter survey (search)
Birds	Random walk, opportunistic observations
Mammals	Tracks and signs, and visual encounter survey

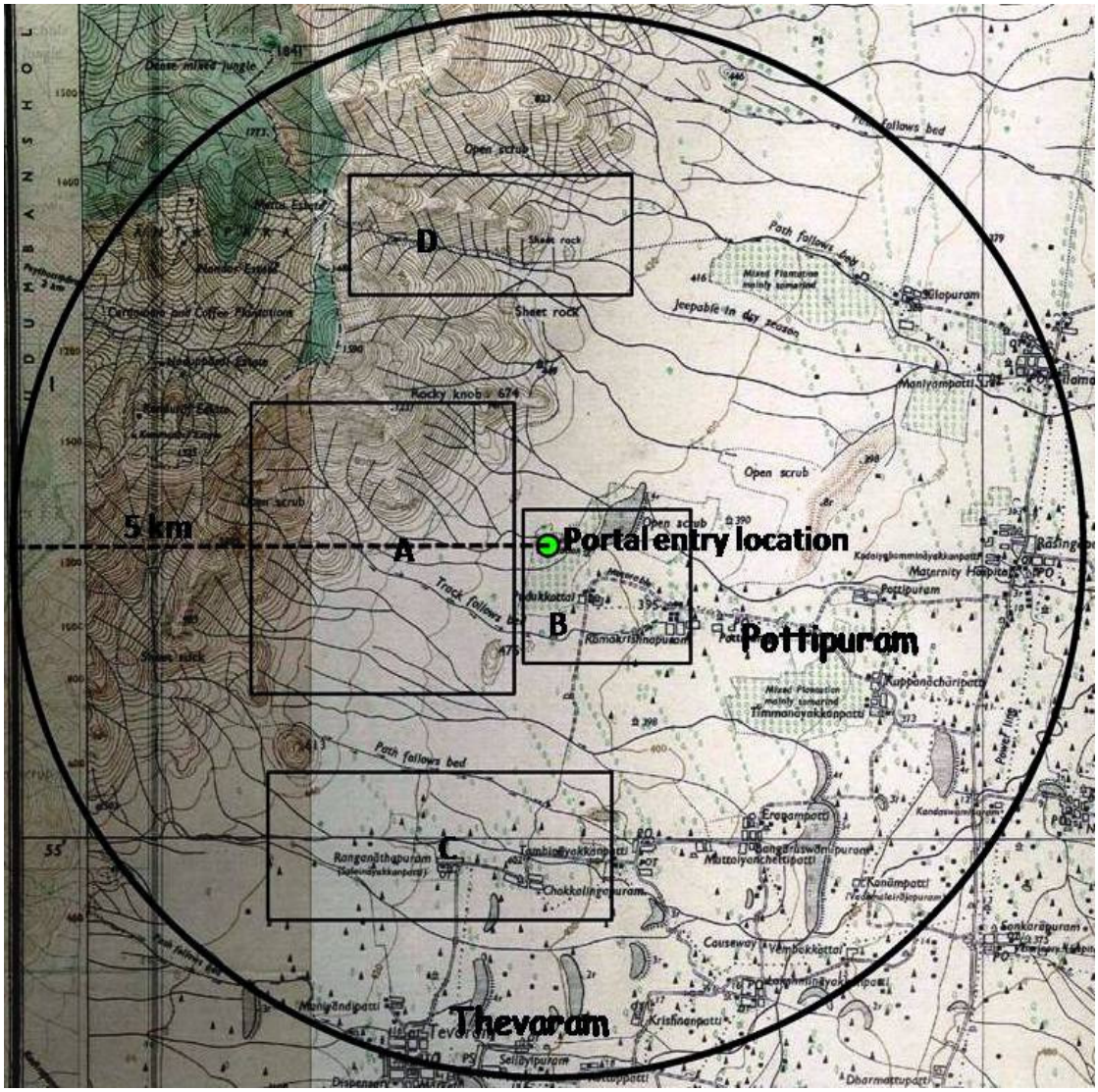

Figure 5: Study area covering 5 km radial distance from the portal (green spot). The squares A, B, C and D represent the intensive study / sample locations

4.2.3 Socioeconomic assessment of the area

To acquire baseline information on the socio-economic status of the area, we depended entirely on data available in public domain maintained by the government agencies. The websites maintained by the Theni district administration and census of India were also referred.

4.3 STUDY AREA

As mentioned earlier, to assess the ecological set-up of the area we have delineated an area falling within 5 Km radial distance taking the portal to the cavern complex as the centre point. Thus, the study area extends to the villages namely Pottippuram, Sankarapuram, Thevaram and Rasingapurm of Tamil Nadu on the north-eastern aspect and some part of Devikulam and Udumban Chola taluks of Kerala on the western side (Figure 5).

4.3.1 Physiography of the region

The proposed INO site is located in the eastern aspect of the southern Western Ghats. The Kodaikanal and Palni hills (~2000 m above MSL) are located to the north eastern part of the study site. The Kumbam valley of the Western Ghats, on the south of the Varashanadu hills (~ 1800 m above MSL), is situated towards the south of the study area. The elevation gradient in the the study area, extending to 78 km^2, ranges from 250 to 1500 m above MSL (Figure 5).

4.3.2 Climate

According to Koppan's climate classification the area falls in the category of "Semi-arid" zone. The climate of the area largely depends on the wind flow pattern through the Kambam valley and the adjacent hillocks. The location of the site on the eastern aspect of the Western Ghats which is leeward to the course of south west monsoon wind from Kerala is the foremost reason for dry weather in the area. The area receives rainfall during 8 months in a year from June to November; prominant rain during the south west monsoon, followed by the north east monsoon. Dry period starts in the middle of December and continues up to May (Figure 7).

The average mean temperature of the area ranges between 24.2^{0}C to 27^{0}C. During March and April the area experience the hottest days (Figure 8). The coldest months are December and January. However, the varaition in the temperature across the months are low in the area ranging only between 3 and 4^{0}C. Similarly, the difference bewteen the minimum and maximum temperature is more or less constant, around 10^{0}C.

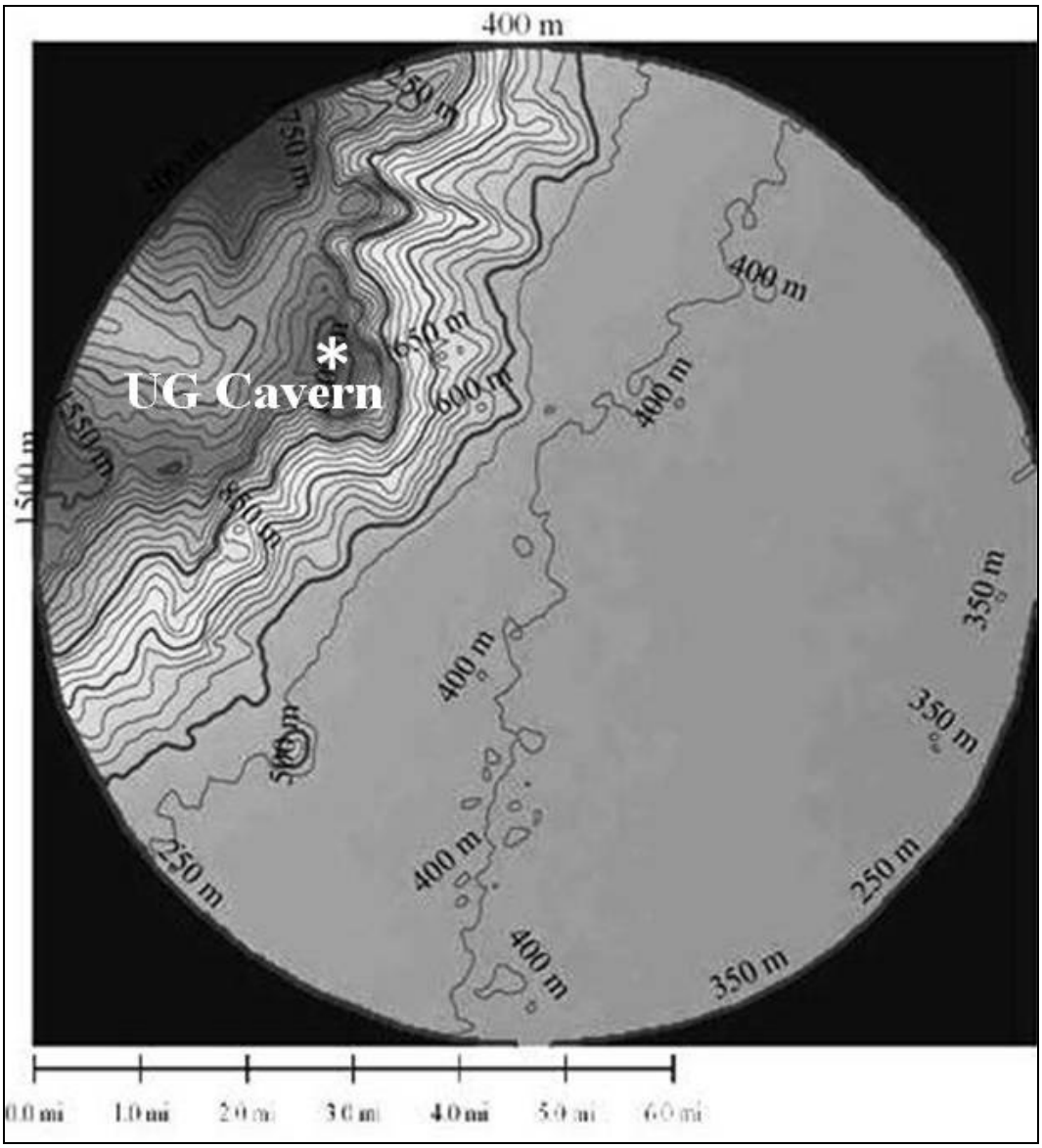

Figure 6: Elevation profile of the proposed INO site.

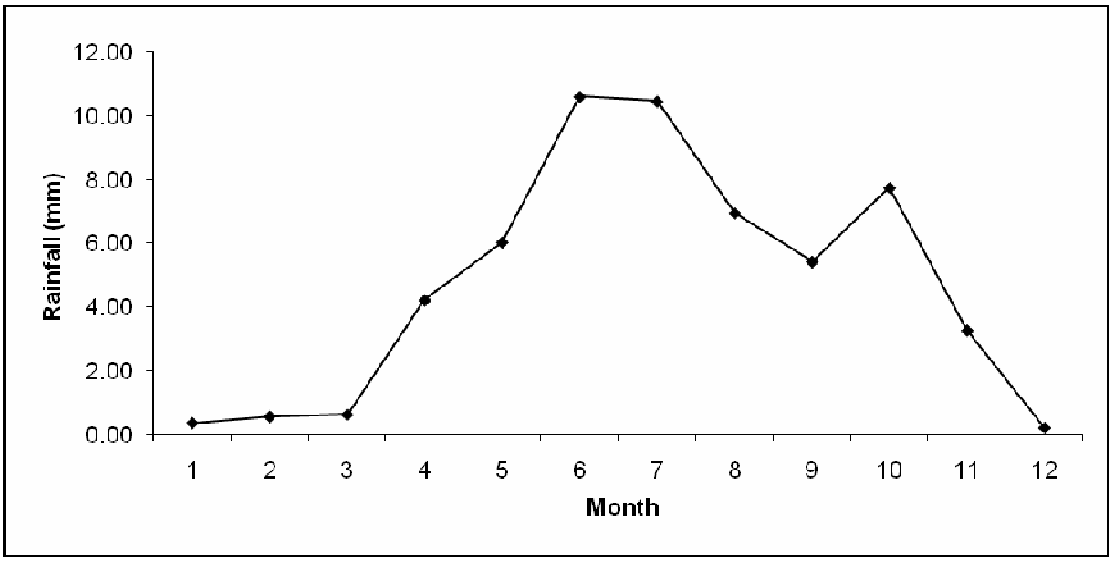

Figure 7: Monthly average rainfall in the study area (Source: IMD 2001-2005)

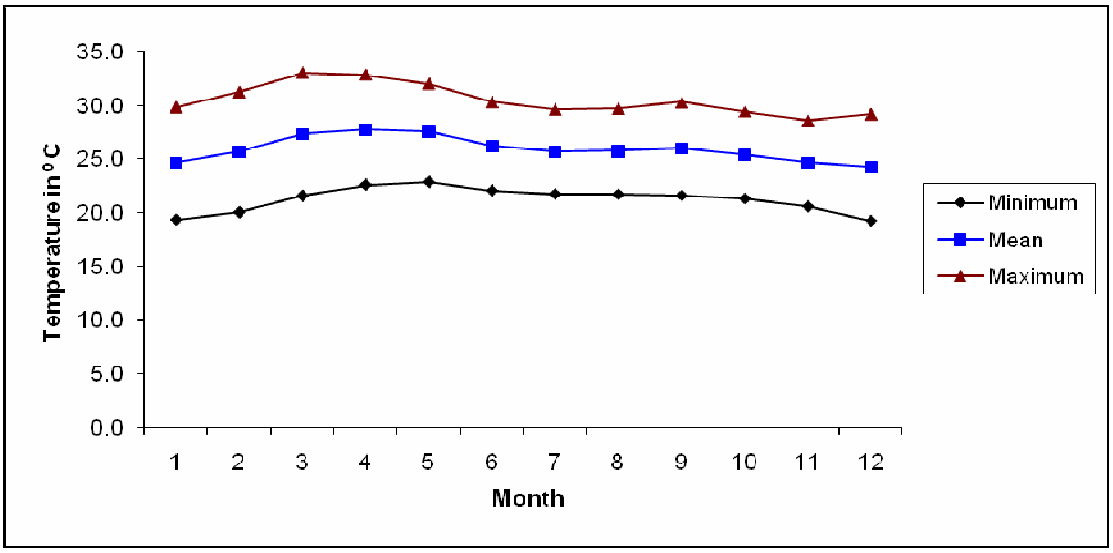

Figure 8: Monthly maximum, minimum, and average temperature (Source: IMD 2001-2005)

4.3.3Socio-economic profile

The total number of people residing in the four rural villages in the Tamil Nadu part of the study area is 28600. The male to female sex ratio of the area is 1:1. Only 59% of the total population is literate. The local inhabitants depend on the near-by Bodinayakannur municipal town and Theni municipal town for various amenities. The population comprising of 15512 labourers greatly depend on the job opportunities in the near-by townships, notwithstanding the lion share of the population in the area depending on agriculture. The area has 9807 marginal agricultural labourers and 2007 main cultivators (Census of India, 2001).

The area is irrigated by the Periyar and Vaigai irrigation projects and major crops raised are millets, groundnut, pulses, tapioca, plantain, rice, and vegetables. In some parts nearby, silk cotton (*Bombax ceiba*) cultivation and mango orchards are also seen. Floriculture is not uncommon in and around the study area. Teak and Jatropha plantation are also seen. The average income of people ranges from Rs 50,000 to 1,00,000/- per annum. Nearby educational institutes include a middle school (~ 2.5 km from the INO site), a high school at Silamalai (~10 km from the site), and a college at Uthamapalayam (~18 km from the site). Nearest government hospital is located at Kuppanarchari Patti, about 6 km away from the site.

In connection with present study, American College, Madurai, was commissioned by the IMSc to carry out a socio-economic survey. As per the study 71% of people are living in own houses, while only 16% are living in *pukka* houses. 62 % of the population does not own any land including cultivable lands.

4.4 ECOLOGICAL SETUP OF THE AREA

4.4.1Forest types within 5 km radial distance from the portal

The forest types found within the study area according to the classification by Champion and Seth (1968) are as follows.

- southern tropical thorn forests (scrub jungles)
- dry mixed deciduous forests

- tropical dry deciduous forests
- riverine forests
- dry savannah forests
- tropical moist deciduous
- southern montane shoal forests
- southern montane humid grasslands

Of these, temperate forests (shola) and southern montane humid grasslands are found exclusively on the Kerala side of the study area. No primary field surveys could be undertaken in those parts falling in Kerala and we had to rely exclusively on secondary information.

4.4.1.1 Southern tropical thorn forests (Scrub Jungles)

Thorny bushes are characteristic of this forest type. These forests are considered to be a result of intensive biotic interferences and relatively poor rain fall. This type of forests is prevalent in plains, mainly at low altitudes, i.e. foot hills where soil is shallow, thin and stony. This area is dominated mainly by xerophytic and hard wood species. Trees are generally short boled with low branching crowns. Lower storey is not well defined in this type of forests. A*cacia farneesiana, A. leucophloea, A. mellifera, Albizia amara, Euphorbia antiquorum, Prosopis juliflora* and *Wrightia tinctoria* are the common trees in this forest types. *Acalypha fruticosa, Barleria acuminata, B. tomentosa, Carissa carandas, C. spinarum, Jatropha gossypifolia, Lantana camara, Opuntia stricta, Pterolobium hexapetalum, Randia dumetorum,* and *Tarenna asiatica* are the common shrubs. Herbaceous plants such as *Acalypha alnifolia, Anisochilus scaber, Barleria prionitis, Paulopsis imbricata, Sida acuta, S. cordifolia, Tephrosia purpurea, Tribulus terrestris* and *Waltheria indica* are commonly seen. Grasses such as *Andropogon pumilus, Bothriochloa pertusa, Brachiaria remota, Chloris barbata* and *Dactyloctenium aegyptium* are also common in these forests.

4.4.1.2 Mixed dry deciduous forests

This type of forest is common at the altitudinal level of 500-700 m above msl. Trees such as *Atalantia monophylla, Acacia chundra, Alangium salviifolium, Albizia odoratissima, Azadirachta indica, Cassia siamea, Chloroxylon swietenia, Diospyros montana, Pleiospermium alatum* and *Streblus asper* are very common in this type of forests. *Cadaba trifoliata, Gmelina asiatica, Grewia flavescens, G. hirsuta, G. villosa, Fluggea leucopyrus, F. virosa, Pavetta indica, Scutia myrtina* and *Ziziphus oenoplia* are the common shrubs. Herbaceous species such as *Achyranthes aspera, Andrographis alata, Blepharis molluginifolia, B. repens, Borreria hispida, Caralumma attenuata, C. umbellata* and *Sansivieria roxburghiana* are also very common in this forest types.

4.4.1.3 Dry deciduous forests

This is the most common forest type in the study area. This forest type is economically very valuable owing to the presence of timber yielding species. This type of forest is common at the altitudinal level of 700-900 m above msl. Dry decidous forests are seen in areas with annual rainfall ranging from 800 mm to 1000 mm and the temperature varying from 18^{o} C to 35^{o} C. Most of the soft quick growing trees occur predominantly whereas shrubs and thin grasses form the ground cover. Trees such as *Bauhinia racemosa, Bombax malabaricum, Capparis grandis, Commiphora berryei, Crateva adansonii, Diospyros chloroxylon, Ehretia ovalifolia, Ficus tomentosa, Flacourtia indica, Gardenia latifolia* and *Gyrocarpus americanus* are common in this forest type. Shrubs like *Consjeera rheedii, Dichrostachys cinerea, Erythroxylum monogynum, Glycosmis pentaphylla, Jatropha peltata, Lantana camara, Mundulia sericea, Maba buxifolia,* and *Tarenna asiatica* are dominant species. Species such as *Abutilon persicum, Anisomeles indica, Asystasia dalzellii, Blumea mollis, Cassia tora, Conyza leucantha, Crotalaria mysorensis, Desmodium triflorum, Indigofera trita, Kalanchoe laciniata, Leanotis nepetiifolia, Stachytarpheta jamaicensis, Synedrella nodiflora* and *Trichodesma zeylanicum* are the common herbaceous plants in this forest type. Grasses such as *Arundinella tuberculata, Chloris dolichostachya, Enteropogon monostachya* and *Eragrostis unioloides* are common in this region.

4.4.1.4 Riverine/riparian forests

A few seasonal streams (depending purely on rains) are seen in the study area. These streams support a stretch of riverine / riparian forests along their banks. Trees such as *Aglaia eleagnoidea*, *Albizia odoratissima, Ficus beddomei, F. hispida, F. microcarpa, F. racemosa, F. tinctoria* ssp. *parasitica, Schefflera stellata, Tricalysia apiocarpa* and *Vitex altissima* are the dominant species in this type of forests. *Anisomeles malabarica, Benkara malabarica, Breynia vitis-idaea, Cipadessa baccifera, Clausena dentata, Helicteres isora, Justicia betonica, Murraya paniculata, Pavetta montana, Rhus mysorensis, Solanum torvum, Strobilanthes cuspidatus* and *Suregada angustifolia* are the dominant shrubs in this forest type. Herbaceous species such as *Aneilema paniculata, Asclepias curassavica, Blumea lacera, Canscora decussata, Centella asiatica, Commelina longifolia, Conyza bonariensis, C. stricta, Crassocephalum crepedioides, Cyperus articulatus, C. corymbosus, C. difformis, C. exaltatus, Eriocaulon thwaitesii, Lindernia antipoda, Ludwigia octavalis, L. perennis, Oxalis corniculata, Polygonum hydropiper, Pouzolzia bennettiana, P. indica* and *Utricularia scandens* are the dominant species here. Species such as *Arundinella ciliata, Cyrtococcum trigonum, Eragrostis viscosa, Garnotia courtallensis, G. elata, G. tenella, Phragmites karka, Tripogon bromoides* and *Zenkaria elegans* are common grasses recorded from this area.

4.4.1.5 Dry savannah forests

These forests are formed as a result of intense biotic interferences and are dispersed throughout the Western Ghats. In these forests, trees are very low in number, stand far apart singly or in small groups amidst spread of heavy grass. Bushy *Phoenix loureirii* is characteristic of these forests. The trees are often unarmed and hollow. Trees such as *Dolichandrone arcuatus, Grewia tiliifolia, Phyllanthus emblica, Terminalia chebula* and *Ziziphus rugosa* are dominant in this forest type. *Chrysopogon asper, C. hackelii, Cymbopogon citratus, Themeda cymbaria* and *T. triandra* are the dominant grasses.

4.4.1.6 Tropical moist deciduous forests

This type of forest is prevalent in moist valleys and on hills at about 1000 m above msl. In the present study area, patches of this forest type are seen scattered here and there especially at higher altitude. Trees such as *Aglaia elaeagnoidea, Albizia odoratissima, Bambusa arundinacea, Canthium dicoccum, Clerodendrum viscosum, Dalbergia latifolia, Debregaesia velutina, Diospyros melanoxylon, Ixora arborea, Macaranga peltata, Mallotus philippensis, Schleichera oleosa*, *Syzygium cumini, Trema orientalis*, *Tricalysia apiocarpa, Trichilia connaroides* and *Vitex altissima* are common in this forest type. Grass species such as *Cyrtococcum trigonum* and *Oplismenus compositus* are common here.

4.4.1.7 Southern montane shola forests

In the study area, these types of forests are seen only in the Kerala side. Temperate or shola forests are confined to moist and sheltered valleys, glens and hollows, at altitudes over 1500 m above msl. Shola forests are characterized by stunted trees having short boles reaching less than 15 m in height. Crowns of the trees are usually dense and rounded with entire coriaceous leaves usually reddish when young, their branches covered with mosses, lichens and other epiphytes. The floristic composition in these forests is mixed with both temperate and tropical elements.

The forests are usually two layered. The top storey consists of trees like *Cinnamomum wightii, Elaeocarpus recurvatus, Eurya japonica, Ilex denticulata, Michelia nilagirica, Microtropis ramiflora, M. microcarpa, Meliosma pinnata, Olea polygama, Photenia integrifolia, Syzygium benthamianum, S. calophyllifolium, S. heyneanum, Symplocos foliosa* etc.

The second storey has shorter trees such as *Cryptocarya lawsonii, Enonymus crenulatus, Ixora notoniana, Microtropis latifolia, Pittosporum neilgherrense, Rapanea wightiana, Schefflera racemosa, S. venulosa, S. wallichiana, Turpinia malabarica, Viburnum erubescens,* and *Vernonia travancorica*.

Shrubs and herbs seen in the ground layer of the shola forests are *Berberis tinctoria, Elatostemma lineolatum, Hypericum mysorense*, *Impatiens hensloviana, Laportea terminalis, Polygala arillata, Sarcococca saligna, Viola serpens, Thalictrum javanicum.* Pteriodophytes are represented by species of *Angiopteris, Lycopodium, Osmunda, Selaginella* etc. Common climbers are *Cayratia pedata* var. *glabra, Clematis wightiana, Piper argyrophyllum, P. schmidtii, P. wightii, Rubia cordifolia, Tylophora fasciculata, T. multiflora, Zehnaria mysorensis.* Common epiphytes are *Bulbophyllum, Coelogyne, Eria, Dendrobium, Oberonia, Gastrochilus, Peperomia, Medinilla, Aeschynanthus, Impatiens, Hoya,* mosses, ferns and lichens.

4.4.1.8 Southern montane humid grasslands

These are found on the higher altitude at about 1600 m above msl. In this type of vegetation grasses, herbs and shrubs are found mixed up in varying proportions. The dominant grasses here include *Arundinella purpurea, A. setosa, A. ciliata, A. pumila, Chrysopogon hackelii, C. verticillatus, C. zeylanicus, Jansenella griffithiana, Paspalum canarae, Poa annua, Themeda triandra, T. tremula, Tripogon ananthaswamianus,* and *T. bromoides*.

Major herbaceous elements belongs to the genera *Anaphalis, Biophytum, Ceropegia, Chlorophytum, Coelogyne, Impatiens, Eriocaulon, Fimbristylis, Helichrysum, Kalanchoe, Oberonia, Parnassia, Pedicularis, Ranunculus, Strobilanthes, Swertia, Thesium,* and *Valeriana*.

Terrestrial orchids such as *Hebenaria elliptica, H. longicorniculata, H. longicornu, H. perrottetiana, H. rariflora, Peristylus aristatus, P. densus, Brachycorythis iantha* and *Satyrium nepalensis* are common. *Elastemma sessile, Eriocaulon longicuspis, E. thwaitesii, Hypoxis aurea, Isachne gracilis, Lecanthus peduncularis* and *Utricularia striatula* are found on moist rocks in grasslands.

4.4.2 Flora

4.4.2.1 Flora at sites A, B and C

The floral composition in the sites A, B, and C (Figure 5) was found more or less similar. Scrub jungle and mixed dry deciduous forests are the dominant vegetation type. Species dominating the area are A*cacia farneesiana, A. leucophloea, A. mellifera, Albizia amara, Euphorbia antiquorum*

and *Prosopis juliflora*. At the first site (A) a small riverine forest patch could be seen on the either side of the seasonal stream flowing down through an altitudinal range of 400 to 1500m above MSL. *Aglaia eleagnoidea*, *Albizia odoratissima, Ficus beddomei, F. hispida, F. microcarpa, F. racemosa, F. tinctoria* ssp. *parasitica, Schefflera stellata, Tricalysia apiocarpa* and *Vitex altissima* are the dominant species in this riverine forest patch. Apart from this, the stream supports several endemic and red-listed (IUCN) plants (Table 9). Human disturbances as grazing and fire-wood collection are common in these regions. In the foot hills of the study area we could observe a large area of teak plantations adjoining a smaller agricultural land.

Table 9: Endemic, IUCN red listed plants in the study sites A, B, and C

No	***Species***	***Family***	***Habit***
1	*Agalaia elaeagnoidea**	Meliaceae	Small tree
2	*Anisochilus scaber**	Lamiaceae	Herb
3	*Aristolochia tagala***	Aristolochiaceae	Climber
4	*Arundinella ciliata**	Poaceae	Herb/Grass
5	*Arundinella setosa**	Poaceae	Herb/Grass
6	*Asystasia dalzelliana**	Acanthaceae	Herb
7	*Barleria acuminata**	Acanthaceae	Shrub
8	*Barleria tomentosa**	Acanthaceae	Shrub
9	*Chrysopogon asper**	Poaceae	Herb/Grass
10	*Chrysopogon hackelii**	Poaceae	Herb/Grass
11	*Crotalaria longipes****	Fabaceae	Shrub
12	*Cynodon barberii**	Poaceae	Herb/Grass
13	*Decalepis hamiltonii***	Asclepiadaceae	Climber
14	*Dicliptera cuneata**	Acanthaceae	Herb
15	*Exacum sessile***	Gentianaceae	Herb
16	*Ficus beddomei**	Moraceae	Tree
17	*Garnotia elata****	Poaceae	Herb/Grass
18	*Jatropha peltata**	Euphorbiaceae	Undershrub
19	*Mucuna pruriens***	Fabaceae	Straggler
20	*Pseudarthria viscida***	Fabaceae	Herb
21	*Strobilanthes consanguinea**	Acanthaceae	Shrub
22	*Strobilanthes cuspidatus**	Acanthaceae	Shrub
23	*Strychnos potatorum***	Loganiaceae	Tree
24	*Tricalysia apiocarpa****	Rubiaceae	Small tree
25	*Tripogon bromoides**	Poaceae	Herb/Grass
26	*Zenkaria elegans**	Poaceae	Herb/Grass

*Endemic to the Peninsular India, ** IUCN Red-listed medicinal plants, ***Endemic to Western Ghats, **** Rare, endemic and endangered.

4.4.2.2 Flora at site D

The vegetation type in site D is dry deciduous dominated by *Commiphora berryei, Crateva adansonii, Diospyros chloroxylon, Ehretia ovalifolia, Ficus tomentosa, Flacourtia indica, Gardenia latifolia* and *Gyrocarpus americanus*. Shrubs such as *Cansjeera rheedii, Dichrostachys cinerea, Erythroxylum monogynum, Glycosmis pentaphylla, Jatropha peltata, Lantana camara, Mundulia sericea, Maba buxifolia* and *Tarenna asiatica* are common in the area. The popular Ondiveerappa temple is located in the foot hills nearby the site. The area is disturbed and polluted from the regular visit by the locals every Thursday. Grazing and fire wood collections are also common here. Large area of teak plantations and patches of cultivation are seen in the valley.

4.4.2.3 Flora in the vicinity of the INO portal

The major vegetation types found to be occurring in this vicinity of entry portal are scrub jungle and mixed dry deciduous forests. The maojr species of trees seen here are *Acacia chundra, A. farneesiana, A. leucophloea, A. nilotica, A. mellifera, A. polyacantha, Aglaia elaeagnoidea, Alangium salviifolium, Albizia amara, A. lebbeck, Annona squamosa, Azdirachta indica, Bambusa arundinacea, Bombax malabaricum, Cassia siamea, Cassine glauca, Capparis grandis, Chloroxylon swietenia, Commiphora caudata, Crateva adansonii, Diospyros montana, Ehretia ovalifolia, Gardenia obovata, Grewia tiliifolia, Holoptelia integrifolia, Ixora arborea, Lannea coromandelica, Euphorbia antiquorum, Fiucs beddomei, F. microcarpa, F. tomentosa, Givitia moluccana, Gyrocarpus americanus, Maba buxifolia, Mallotus philippensis, Phyllanthus emblica, Premna corymbosa, P. tomentosa, Prosopis juliflora, Sapindus emarginatus, Streblus asper, Strychnos nux-vomica, S. potatorum, Tricalysia apiocarpa, Vitex altissima, V. negundo, Wrightia tinctoria, Zizyphus mauritiana.*

Major shrubs recorded in the portal entry and nearby areas are *Abutilon indicum, A. hirtum, Acacia caesia, A. torta, Acalypha fruiticosa, Anisomeles malabarica, Atalantia monophylla, Azima tetrcantha, Barleria acuminata, B. tomentosa, Benkara malabarica, Cadaba trifoliata, Capparis sepiaria, C. zeylanica, Carmona retusa, Carissa carandas, C. spinarum, Cassia auriculata, Cansjeera rheedii, Commiphora berryi, Dichrostachys cinerea, Dodonaea*

angustifolia, Fluggea leucopyrus, F. virosa, Glycosmis mauritiana, G. pentaphylla, Gmelina asiatica, Grewia hirsuta, G. villosa, Helicteres isora, Jasminum auriculatum, Jatropha gossypifolia, J. peltata, Justicia betonica, Kleinia grandiflora, Lantana camara, Loseneeriella obtusifloia, Maytenus ovata, Mundulia sericea, Murraya paniculata, Pavetta indica, Phyllanthus polyphyllus, Pleiospermium alatum, Pterolobium hexapetalum, Randia dumetorum, Salacia reticulata, Scutia myrtina, Solanum pubescens, Strobilanthes consanguinea, S. cuspidatus, Suregada angustifolia, Tarenna asiatica, Toddalia asiatica, Ventilago maderaspatana and *Ziziphus oenoplia*.

Common herbaceous plants are *Abutilon persicum, Acalypha indica, Achyranthes aspera, Aerva lanata, A. persica, Alloteropsis cimcinna, Anisochilus carnosus, A. scaber, Anisomeles indica, Apluda mutica, Aristida adscensionis, A. funiculata, A. hystrix, Barleria prionitis, Blepharis maderaspatensis, B. molluginifolia, Bothriochloa pertusa, Caralluma attenuata, C. umbellata, Cassia occidentalis, C. tora, Cenchrus ciliaris, Chloris barbata, C. dolichostachya, Desmodium triflorum, Eragrostis atrovirens, E. viscosa, E. hirta, E. thymifolia, Justicia simplex, Lantana wightiana, Leucas aspera, L. biflora, Mollugo cerviana, M. nudicaulis, M. pentaphylla, Monothecium aristatum, Nothosaerva brachiata, Ocimum canum, Oldenlandia biflora, O. corymbosa, O. umbellata, Oxalis corniculata, Passiflora foetida, Pavonia procumbens, P. zeylanica, Peristrophe bicalyculata, Perotis indica, Phyllanthus amarus, P. maderaspatensis, Polycarpaea corymbosa, Pseudarthria viscida, Rhynchosia minima, Ruelia patula, Sansivieria roxburghiana, Secamone emitica, Sida acuta, S. cordata, Tephrosia purpurea, T. villosa, Tridax procumbens, Triumfetta pentandra, Vernonia cinerea, Vicoa indica* and *Waltheria indica*.

4.4.2.4 Floral analysis

During the present study, in total 517 species belonging to 312 genera and spreading over 81 families were recorded in the study area. Among the 517 species, trees were 101 species (Appendix 2), shrubs 69 species (Appendix 3), herbaceous plants were 198 species (Appendix 4), , stragglers/climbers 86 species (Appendix 5), and grasses 63 species (Appendix 6, excluding *Bambusa arundinacea*, which is included under trees due to its arborescent nature). Thus, in the figure 9 the species is put under trees.

Of the 81 plant families reported from the study area, Poaceae is the dominant one represented by 64 species followed by Fabaceae, Asteraceae, Euphorbiaceae and Acanthaceae with 39, 28, 27 and 21 species each respectively (Figure 10). Among the 312 genera recorded from the study area *Acacia* is the dominant genus with 10 species followed by *Cassia* and *Ficus* with 8 species each, *Capparis* and *Crotalaria* with 7 species each, *Phyllanthus* 6 species and *Solanum* with 5 species. Among the 517 species recorded in the present study area only one species i.e. *Arundinella tuberculata* forms an addition to the flora of Tamil Nadu (Kabeer and Nair, 2009).

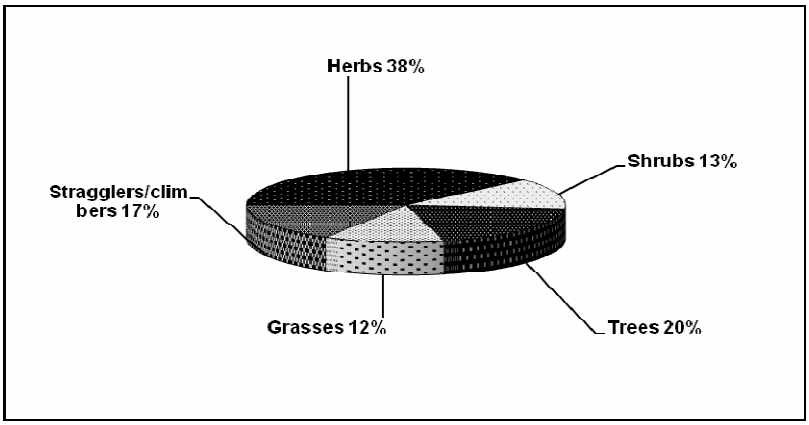

Figure 9: Habitwise analysis of plant species in the proposed INO site

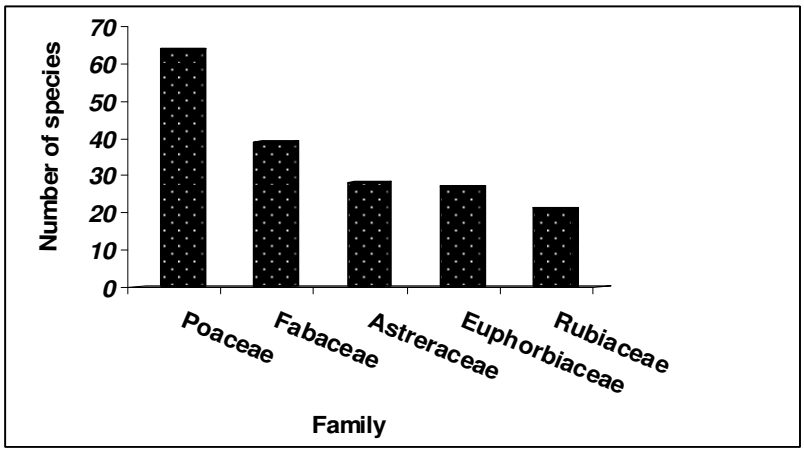

Figure 10: Dominant plant families of the study area

4.4.2.5 Endemic, endangered / threatened IUCN red listed plants in the area

A total of 40 endemic, endangered and IUCN red listed plants are found occurring in the study area (Table 10). However, none of these species are restricted to the area. Among the 40 species, 34 are endemic, distributed only in the hills of Indian subcontinent (Henry et al., 1978; Ahmedullah and Nayar, 1987; Nayar, 1996). Rest 6 species, although are considered endangered / threatened /vulnerable, are distributed widely elsewhere including outside the country. Of the 40 endemic species recorded two species such as *Garnotia elata* and *Tricalysia apiocarpa* are endemic to Western Ghats and rest of the species are endemic to Peninsular india (Ahmedullah and Nayar, 1987; Nayar, 1996). Two species namely *Crotalaria longipes* and *Indigofera barberii* are rare and endangered species reported in the Red Data Book of Indian plants (Nayar and Sastry, 1987-1990). Nine species namely *Aristolochia indica, Aristolochia tagala, Cadaba trifoliata, Decalepis hamiltonii, Exacum sessile, Moringa concanensis, Mucuna pruriens, Pseudarthria viscida* and *Strychnos potatorum* are endangered / threatened IUCN red-listed medicinal plants. Nevertheless, these are also not limited to the study area and are found elsewhere.

Table 10: Endemic, endangered/threatened IUCN red listed plants in the study area

No	***Plant species***	***Family***	***Habit***
1	*Aglaia elaeagnoidea**	Meliaceae	Small tree
2	*Alstonia venenata**	Apocynaceae	Shrub
3	*Anisochilus scaber**	Lamiaceae	Herb
4	*Aristolochia indica***	Aristolochiaceae	Climber
5	*Aristolochia tagala***	Aristolochiaceae	Climber
6	*Arundinella ciliata**	Poaceae	Herb/Grass
7	*Arundinella setosa**	Poaceae	Herb/Grass
8	*Arundinella tuberculata****	Poaceae	Herb/Grass
9	*Asystasia dalzelliana**	Acanthaceae	Herb
10	*Atalantia racemosa**	Rutaceae	Tree
11	*Barleria acuminata**	Acanthaceae	Shrub
12	*Barleria tomentosa**	Acanthaceae	Shrub
13	*Cadaba trifoliata***	Capparidaceae	Shrub
14	*Chrysopogon asper**	Poaceae	Herb/Grass
15	*Chrysopogon hackelii**	Poaceae	Herb/Grass
16	*Crotalaria longipes*****	Fabaceae	Shrub
17	*Cynodon barberii**	Poaceae	Herb/Grass
18	*Decalepis hamiltonii***	Asclepiadaceae	Climber

19	*Dicliptera cuneata**	Acanthaceae	Herb
20	*Exacum sessile***	Gentianaceae	Herb
21	*Ficus beddomei**	Moraceae	Tree
22	*Garnotia elata**	Poaceae	Herb/Grass
23	*Indigofera barberii*****	Fabaceae	Herb
24	*Jatropha peltata**	Euphorbiaceae	Undershrub
25	*Leucas vestita**	Lamiaceae	Herb
26	*Maba buxifolia**	Ebenaceae	Tree
27	*Micrargeria wightii**	Scrophulariaceae	Herb
28	*Moringa concanensis***	Moringaceae	Tree
29	*Mucuna pruriens***	Fabaceae	Straggler
30	*Pseudarthria viscida***	Fabaceae	Herb
31	*Sarcostemma brunoniana**	Asclepiadaceae	Straggler
32	*Sporobolous wallichii**	Poaceae	Herb/Grass
33	*Strobilanthes consanguinea**	Acanthaceae	Shrub
34	*Strobilanthes cuspidatus**	Acanthaceae	Shrub
35	*Strychnos potatorum***	Loganiaceae	Tree
36	*Suregada angustifolia**	Euphorbiaceae	Shrub
37	*Tribulus subramaniamii**	Zygophyllaceae	Herb
38	*Tricalysia apiocarpa**	Rubiaceae	Small tree
39	*Tripogon bromoides**	Poaceae	Herb/Grass
40	*Zenkaria elegans**	Poaceae	Herb/Grass
*Endemic, ** IUCN Red-listed medicinal plants, *** Endemic and new record for Tamil Nadu, **** Rare, endemic and endangered.			

Of the 8 forest types found in the area, the riverine forests support several endemic plant species. Among the 40 species of conservation importance seen in the present study area, most (18 species) are noticed in riverine forests. The species recorded in the riverine forest are listed in the following table (Table 11).

Among the 40 species of conservation importance recorded in the study area, species such as *Anisochilus scaber, Aristolochia tagala, Barleria acuminata, B. tomentosa, Cadaba trifoliata, Cynodon barberii, Decalepis hamiltonii, Dicliptera cuneata, Indigofera barberii, Moringa concanensis, Mucuna pruriens, Pseudarthria viscida, Sarcostemma brunoniana, Strobilanthes consanguinea, Strychnos potatorum* and *Tribulus subramaniamii* are recorded in the vicinity of the INO portal.

Table 11: Endemic/endangered plants in the riverine forests of the study area

No	***Plant species***	***Habit***	***Family***
1	*Aglaia elaeagnoidea*	Small tree	Meliaceae
2	*Alstonia venenata*	Shrub	Apocynaceae
3	*Arundinella ciliata*	Herb	Poaceae
4	*Arundinella tuberculata*	Herb	Poaceae
5	*Cadaba trifoliata*	Shrub	Capparidaceae
6	*Chrysopogon asper*	Herb	Poaceae
7	*Chrysopogon hackelii*	Herb	Poaceae
8	*Crotalaria longipes*	Shrub	Fabaceae
9	*Exacum sessile*	Herb	Gentianaceae
10	*Ficus beddomei*	Tree	Moraceae
11	*Garnotia elata*	Herb	Poaceae
12	*Mucuna pruriens*	Straggler	Fabaceae
13	*Strobilanthes cuspidatus*	Shrub	Acanthaceae
14	*Strychnos potatorum*	Small tree	Loganiaceae
15	*Suregada angustifolia*	Small tree	Euphorbiaceae
16	*Tricalysia apiocarpa*	Small tree	Rubiaceae
17	*Tripogon bromoides*	Herb	Poaceae
18	*Zenkaria elegans*	Herb	Poaceae

4.4.3 Phytosociology

4.4.3.1 Tree Community

The data on vegetation collected from the study area analyzed for various phytosociological parameters shows the following.

Species diversity and richness: A total of 892 trees, belonging to 63 species, 47 genera spread over 27 families, were recorded in the study area. The tree community parameters, computed from the data are presented in the Table 12. Among trees, *Euphorbia antiquorum* was represented by maximum number of individuals (n = 92) followed by *Albizia amara* (n = 74), *Chloroxylon swietenia* (n = 70), *Streblus asper* (n = 67) and *Aglaia elaeagnoidea* (n = 64). Of the 27 families recorded here, the family Mimosaceae is the most dominant family having 9 species followed by Moraceae (6 species) and Caesalpiniaceae, Euphorbiaceae, Rubiaceae and Rutaceae (4 species each).

Highest density was recorded for *Euphorbia antiquorum* (2.63) followed by *Albizia amara* (2.11), *Chloroxylon swietenia* (2.00), *Streblus asper* (1.91) and *Aglaia elaeagnoidea* (1.83). In terms of relative density highest value was recorded for *Euphorbia antiquorum* (10.31) followed by *Albizia amara* (8.29), *Chloroxylon swietenia* (7.85), *Streblus asper* (7.51) and *Aglaia elaeagnoidea* (7.17). The Shannon-Weiner diversity for tree community in the study area was 3.492.

***Importance Value Index*:** Highest Important Value Index was recorded for *Albizia amara* (40.94) followed by *Euphorbia antiquorum* (33.21), *Chloroxylon swietenia* (23.80), *Aglaia elaeagnoidea* (20.55) and *Acacia farnesiana* (17.90).

Table 12: Tree community structure in the study area

Species	***N***	***Qn***	***GBH***	***F (%)***	***A***	***De***	***RF***	***RA***	***RD***	***BA***	***Do***	***RDo***	***IVI***
Euphorbia antiquorum	92	26	55.8	74.3	3.5	2.6	7.4	2.1	10.3	2446	0.1	15.5	33.2
Albizia amara	74	26	71.2	74.3	2.9	2.1	7.4	1.7	8.3	3982	0.2	25.3	40.9
Chloroxylon swietenia	70	28	40.1	80	2.5	2	7.9	1.5	7.9	1264	0.1	8	23.8
Streblus asper	67	16	28.8	45.7	4.2	1.9	4.5	2.5	7.5	650	0	4.1	16.2
Aglaia elaeagnoidea	64	9	46.6	25.7	7.1	1.8	2.6	4.3	7.2	1706	0.1	10.8	20.6
Acacia farnesiana	37	20	40.3	57.1	1.9	1.1	5.7	1.1	4.2	1273	0.1	8.1	17.9
Cassia siamea	37	9	35.5	25.7	4.1	1.1	2.6	2.5	4.2	992	0.1	6.3	13
Diospyros montana	29	17	12.1	48.6	1.7	0.8	4.8	1	3.3	115	0	0.7	8.8
Prosopis juliflora	27	16	31	45.7	1.7	0.8	4.5	1	3	756	0	4.8	12.4
Atalantia monophylla	26	14	18.6	40	1.9	0.7	4	1.1	2.9	273	0	1.7	8.6
Strychnos potatorum	23	3	7	8.6	7.7	0.7	0.9	4.6	2.6	38.7	0	0.3	3.7
Acacia leucophloea	21	15	11.3	42.9	1.4	0.6	4.3	0.8	2.4	101	0	0.6	7.2
Azadirachta indica	21	12	11	34.3	1.8	0.6	3.4	1.1	2.4	94.4	0	0.6	6.4
Lannea coromandelica	16	6	24.8	17.1	2.7	0.5	1.7	1.6	1.8	484	0	3.1	6.6
Pleiospermium alatum	16	7	10.6	20	2.3	0.5	2	1.4	1.8	88.5	0	0.6	4.3
Vepris bilocularis	15	8	11.6	22.9	1.9	0.4	2.3	1.1	1.7	106	0	0.7	4.6
Thevetia peruviana	14	1	4.9	2.9	14	0.4	0.3	8.4	1.6	18.6	0	0.1	2
Ficus tomentosa	13	6	26.7	17.1	2.2	0.4	1.7	1.3	1.5	559	0	3.6	6.7
Strychnos nux-vomica	13	7	8.2	20	1.9	0.4	2	1.1	1.5	52.2	0	0.3	3.8
Acacia polyacantha	12	3	7.7	8.6	4	0.3	0.9	2.4	1.4	47	0	0.3	2.5
Diospyros chloroxylon	11	5	3.5	14.3	2.2	0.3	1.4	1.3	1.2	9.6	0	0.1	2.7
Sapindus emarginatus	11	7	5.6	20	1.6	0.3	2	0.9	1.2	24.3	0	0.2	3.4
Cassine glauca	10	5	6.5	14.3	2	0.3	1.4	1.2	1.1	33	0	0.2	2.8
Maba buxifolia	10	3	2.8	8.6	3.3	0.3	0.9	2	1.1	6.3	0	0	2
Tricalysia apiocarpa	10	5	8.5	14.3	2	0.3	1.4	1.2	1.1	56.4	0	0.4	2.9
Acacia chundra	9	5	3.9	14.3	1.8	0.3	1.4	1.1	1	12	0	0.1	2.5

Ficus beddomei	9	6	16.8	17.1	1.5	0.3	1.7	0.9	1	222	0	1.4	4.1
Ziziphus trinervia	9	4	3.8	11.4	2.3	0.3	1.1	1.3	1	11.6	0	0.1	2.2
Jatropha curcus	8	1	4.2	2.9	8	0.2	0.3	4.8	0.9	13.6	0	0.1	1.3
Albizia lebbeck	7	5	5.9	14.3	1.4	0.2	1.4	0.8	0.8	27.7	0	0.2	2.4
Givotia moluccana	7	3	8.9	8.6	2.3	0.2	0.9	1.4	0.8	62	0	0.4	2
Commiphora berryi	6	5	5.1	14.3	1.2	0.2	1.4	0.7	0.7	20.4	0	0.1	2.2
Commiphora caudata	6	2	7.8	5.7	3	0.2	0.6	1.8	0.7	47.8	0	0.3	1.5
Holoptelia integrifolia	6	5	2.8	14.3	1.2	0.2	1.4	0.7	0.7	6.2	0	0	2.1
Premna corymbosa	6	2	2.5	5.7	3	0.2	0.6	1.8	0.7	4.9	0	0	1.3
Albizia odoratissima	5	2	3.6	5.7	2.5	0.1	0.6	1.5	0.6	10.2	0	0.1	1.2
Bambusa arundinacea	5	5	9.1	14.3	1	0.1	1.4	0.6	0.6	64.6	0	0.4	2.4
Gyrocarpus americanus	5	3	3.2	8.6	1.7	0.1	0.9	1	0.6	8.3	0	0.1	1.5
Helicteres isora	5	1	4	2.9	5	0.1	0.3	3	0.6	12.4	0	0.1	0.9
Acacia planifrons	4	2	3.8	5.7	2	0.1	0.6	1.2	0.5	11.4	0	0.1	1.1
Dalbergia paniculata	4	2	1.5	5.7	2	0.1	0.6	1.2	0.5	1.7	0	0	1
Ehretia ovalifolia	4	1	2.3	2.9	4	0.1	0.3	2.4	0.5	4.1	0	0	0.8
Ficus microcarpa	4	3	2.7	8.6	1.3	0.1	0.9	0.8	0.5	5.7	0	0	1.3
Gardenia obovata	4	1	1.9	2.9	4	0.1	0.3	2.4	0.5	2.9	0	0	0.8
Gmelina arborea	4	1	1.5	2.9	4	0.1	0.3	2.4	0.5	1.8	0	0	0.7
Ziziphus mauritiana	4	1	2.4	2.9	4	0.1	0.3	2.4	0.5	4.6	0	0	0.8
Acacia mellifera	3	1	2.5	2.9	3	0.1	0.3	1.8	0.3	5	0	0	0.7
Bombax malabaricum	3	1	2.8	2.9	3	0.1	0.3	1.8	0.3	5.9	0	0	0.7
Celtis philippensis	3	1	2.8	2.9	3	0.1	0.3	1.8	0.3	6	0	0	0.7
Grewia tiliifolia	3	2	1.3	5.7	1.5	0.1	0.6	0.9	0.3	1.4	0	0	0.9
Wrightia tinctoria	3	2	1.9	5.7	1.5	0.1	0.6	0.9	0.3	2.7	0	0	0.9
Ailanthes excelsa	2	1	1.2	2.9	2	0.1	0.3	1.2	0.2	1.1	0	0	0.5
Canthium dicoccum	2	1	1.4	2.9	2	0.1	0.3	1.2	0.2	1.6	0	0	0.5
Ficus racemosa	2	1	2.2	2.9	2	0.1	0.3	1.2	0.2	3.8	0	0	0.5
Ficus tinctoria ssp. *Parasitica*	2	2	1.3	5.7	1	0.1	0.6	0.6	0.2	1.3	0	0	0.8
Ixora arborea	2	1	0.8	2.9	2	0.1	0.3	1.2	0.2	0.6	0	0	0.5
Vitex negundo	2	1	1.4	2.9	2	0.1	0.3	1.2	0.2	1.5	0	0	0.5
Acacia nilotica	1	1	0.6	2.9	1	0	0.3	0.6	0.1	0.3	0	0	0.4
Cereus pterogonus	1	1	2.4	2.9	1	0	0.3	0.6	0.1	4.6	0	0	0.4
Crateva adansonii	1	1	0.3	2.9	1	0	0.3	0.6	0.1	0.1	0	0	0.4
Dicrostachys cinerea	1	1	0.3	2.9	1	0	0.3	0.6	0.1	0.1	0	0	0.4
Mallotus philippensis	1	1	0.5	2.9	1	0	0.3	0.6	0.1	0.2	0	0	0.4

Note: n = number of Individuals, Qn = number of qudrats where the species occur, GBH = Girth at Breast Height in centimeters, F = Frequency, A =Abundance, Dn = Density, RF = Relative frequency, RA = Relative abundance, RDn = Relative density, BA = Basal Area, Do = Dominance, R.Do = Relative dominance, IVI = Importance Value Index

4.4.3.2 Shrub Community

Species Diversity and Richness: A total of 2802 individuals belonging to 89 shrub species belonging to 73 genera spread over 39 families were recorded in the study area. The shrub community parameters are provided in Table 13. Among the 89 species, *Tarenna asiatica* was seen in highest number (n = 344) followed by *Barleria acuminata* (n = 276), *Aglaia elaegnoidea* (n = 213), *Sansivieria roxburghiana* (n = 201) and *Glycosmis mauritiana* (n = 142). Of the 41 families recorded here, Euphorbiaceae stands first with 10 species followed by Tiliaceae (n = 6), Rubiaceae (n = 5) and Acanthaceae, Fabaceae, Mimosaceae and Rutaceae having 4 species each.

Highest density was recorded for *Tarenna asiatica* (9.83) followed by *Barleria acuminata* (7.89), *Aglaia elaeagnoidea* (6.09), *Sansivieria roxburghiana* (5.74) and *Glycosmis mauritiana* (4.06). Likewise, relative density was found highest for *Tarenna asiatica* (12.28) followed by *Barleria acuminata* (9.85), *Agalia elaeagnoidea* (7.60), *Sansivieria roxburghiana* (7.17) and *Glycosmis mauritiana* (5.07). The Shannon-Weiner diversity for shrub community in total in the study area was 3.609.

Importance Value Index*:* Of the several shrub species seen during the study, highest IVI was recorded for *Tarenna asiatica* (19.48) followed by *Barleria acuminata* (15.93), *Agalia elaeagnoidea* (12.33), *Sansivieria roxburghiana* (8.52) and *Glycosmis mauritiana* (6.87).

Table 13. Shrub community structure in the study area

Species	***n***	***Qn***	***F***	***A***	***Dn***	***RF***	***RA***	***RD***	***IVI***
Tarenna asiatica	344	32	91.4	10.8	9.83	7.21	2.52	12.28	19.5
Barleria acuminata	276	27	77.1	10.2	7.89	6.08	2.40	9.85	15.9
Agalaia elaeagnoidea	213	21	60.0	10.1	6.09	4.73	2.38	7.60	12.3
Sansivieria roxburghiana	201	6	17.1	33.5	5.74	1.35	7.86	7.17	8.52
Glycosmis mauritiana	142	8	22.9	17.8	4.06	1.80	4.17	5.07	6.87
Benkara malabarica	106	13	37.1	8.15	3.03	2.93	1.91	3.78	6.71
Strobilanthus cuspidatus	94	9	25.7	10.4	2.69	2.03	2.45	3.35	5.38
Mundulia sericea	80	14	40.0	5.71	2.29	3.15	1.34	2.86	6.01
Fluggea leucopyros	74	14	40.0	5.29	2.11	3.15	1.24	2.64	5.79
Anisomeles malabarica	70	10	28.6	7.00	2.00	2.25	1.64	2.50	4.75

Helicteres isora	62	10	28.5	6.20	1.77	2.25	1.46	2.21	4.46
Barleria tomentosa	58	7	20.0	8.29	1.66	1.58	1.94	2.07	3.65
Carmona retusa	55	8	22.9	6.88	1.57	1.80	1.61	1.96	3.76
Acalypha fruiticosa	53	9	25.7	5.89	1.51	2.03	1.38	1.89	3.92
Salacia reticulata	53	13	37.1	4.08	1.51	2.93	0.96	1.89	4.82
Randia dumetorum	46	10	28.6	4.60	1.31	2.25	1.08	1.64	3.89
Dodonaea angustifolia	38	5	14.3	7.60	1.09	1.13	1.78	1.36	2.48
Acacia torta	37	7	20.0	5.29	1.06	1.58	1.24	1.32	2.90
Maba buxifolia	37	5	14.3	7.40	1.06	1.13	1.74	1.32	2.45
Ziziphus oenoplia	37	15	42.9	2.47	1.06	3.38	0.58	1.32	4.70
Streblus asper	35	5	14.3	7.00	1.00	1.13	1.64	1.25	2.38
Jatropha gossypifolia	34	6	17.1	5.67	0.97	1.35	1.33	1.21	2.56
Phyllanthus reticulatus	31	7	20.0	4.43	0.89	1.58	1.04	1.11	2.68
Combretum ovalifolium	27	5	14.3	5.40	0.77	1.13	1.27	0.96	2.09
Azima tetracantha	26	9	25.7	2.89	0.74	2.03	0.68	0.93	2.95
Dichrostachys cinerea	26	4	11.4	6.50	0.74	0.90	1.53	0.93	1.83
Jatropha peltata	26	5	14.3	5.20	0.74	1.13	1.22	0.93	2.05
Cassia auriculata	23	8	22.9	2.88	0.66	1.80	0.67	0.82	2.62
Grewia disperma	22	7	20.0	3.14	0.63	1.58	0.74	0.79	2.36
Lantana camara	21	5	14.3	4.20	0.60	1.13	0.99	0.75	1.88
Cissus quadrangularis	19	6	17.1	3.17	0.54	1.35	0.74	0.68	2.03
Fluggea virosa	18	4	11.4	4.50	0.51	0.90	1.06	0.64	1.54
Ipomoea staphylina	18	8	22.9	2.25	0.51	1.80	0.53	0.64	2.44
Pavetta indica	17	5	14.3	3.40	0.49	1.13	0.80	0.61	1.73
Cipadessa baccifera	16	2	5.71	8.00	0.46	0.45	1.88	0.57	1.02
Salacia sp.	16	3	8.57	5.33	0.46	0.68	1.25	0.57	1.25
Capparis sepiaria	15	4	11.4	3.75	0.43	0.90	0.88	0.54	1.44
Ventilago maderaspatana	15	4	11.4	3.75	0.43	0.90	0.88	0.54	1.44
Gmelina asiatica	14	4	11.4	3.50	0.40	0.90	0.82	0.50	1.40
Scutia myrtina	14	6	17.1	2.33	0.40	1.35	0.55	0.50	1.85
Atalantia monophylla	13	3	8.57	4.33	0.37	0.68	1.02	0.46	1.14
Cansjeera rheedii	12	4	11.4	3.00	0.34	0.90	0.70	0.43	1.33
Cocculus hirsutus	12	2	5.71	6.00	0.34	0.45	1.41	0.43	0.88
Grewia villosa	12	4	11.4	3.00	0.34	0.90	0.70	0.43	1.33
Solanum pubescens	12	3	8.57	4.00	0.34	0.68	0.94	0.43	1.10
Abutilon indicum	10	4	11.4	2.50	0.29	0.90	0.59	0.36	1.26
Albizia amara	10	3	8.57	3.33	0.29	0.68	0.78	0.36	1.03
Breynia vitis-idaea	10	1	2.86	10.0	0.29	0.23	2.35	0.36	0.58

Grewia hirsuta	10	3	8.57	3.33	0.29	0.68	0.78	0.36	1.03
Justicia betonica	10	2	5.71	5.00	0.29	0.45	1.17	0.36	0.81
Annona squamosa	9	2	5.71	4.50	0.26	0.45	1.06	0.32	0.77
Cadaba indica	9	4	11.4	2.25	0.26	0.90	0.53	0.32	1.22
Carissa carandas	9	5	14.3	1.80	0.26	1.13	0.42	0.32	1.45
Cocculus pendulus	9	5	14.3	1.80	0.26	1.13	0.42	0.32	1.45
Jasminum auriculatum	9	4	11.4	2.25	0.26	0.90	0.53	0.32	1.22
Grewia flavescens	8	2	5.71	4.00	0.23	0.45	0.94	0.29	0.74
Wrightia tinctoria	8	2	5.71	4.00	0.23	0.45	0.94	0.29	0.74
Grewia rhomboidea	7	2	5.71	3.50	0.20	0.45	0.82	0.25	0.70
Azadirachta indica	6	2	5.71	3.00	0.17	0.45	0.70	0.21	0.66
Chromolaena odorata	6	2	5.71	3.00	0.17	0.45	0.70	0.21	0.66
Diospyros montana	6	2	5.71	3.00	0.17	0.45	0.70	0.21	0.66
Jatropha curcus	6	1	2.86	6.00	0.17	0.23	1.41	0.21	0.44
Parsonsia alboflavescens	6	2	5.71	3.00	0.17	0.45	0.70	0.21	0.66
Pleiospermium alatum	6	2	5.71	3.00	0.17	0.45	0.70	0.21	0.66
Sapindus emarginatus	6	1	2.86	6.00	0.17	0.23	1.41	0.21	0.44
Ichnocarpus frutescens	5	2	5.71	2.50	0.14	0.45	0.59	0.18	0.63
Suregada angustifolia	5	1	2.86	5.00	0.14	0.23	1.17	0.18	0.40
Tetrastigma lanceolaria	5	2	5.71	2.50	0.14	0.45	0.59	0.18	0.63
Cissus vitigenea	4	1	2.86	4.00	0.11	0.23	0.94	0.14	0.37
Commiphora berryi	4	1	2.86	4.00	0.11	0.23	0.94	0.14	0.37
Euphorbia antiquorum	4	1	2.86	4.00	0.11	0.23	0.94	0.14	0.37
Grewia orbiculata	4	1	2.86	4.00	0.11	0.23	0.94	0.14	0.37
Opuntia stricta	4	1	2.86	4.00	0.11	0.23	0.94	0.14	0.37
Pouzolzia bennettiana	4	1	2.86	4.00	0.11	0.23	0.94	0.14	0.37
Acacia chundra	3	1	2.86	3.00	0.09	0.23	0.70	0.11	0.33
Bambusa arundinacea	3	2	5.71	1.50	0.09	0.45	0.35	0.11	0.56
Canthium dicoccum	3	1	2.86	3.00	0.09	0.23	0.70	0.11	0.33
Jasminum rigidum	3	1	2.86	3.00	0.09	0.23	0.70	0.11	0.33
Passiflora foetida	3	1	2.86	3.00	0.09	0.23	0.70	0.11	0.33
Capparis zeylanica	2	1	2.86	2.00	0.06	0.23	0.47	0.07	0.30
Carissa spinarum	2	1	2.86	2.00	0.06	0.23	0.47	0.07	0.30
Loseneeriella obtusifolia	2	1	2.86	2.00	0.06	0.23	0.47	0.07	0.30
Mucuna atropurpurea	2	1	2.86	2.00	0.06	0.23	0.47	0.07	0.30
Murraya paniculata	2	1	2.86	2.00	0.06	0.23	0.47	0.07	0.30
Pterolobium hexapetalum	2	1	2.86	2.00	0.06	0.23	0.47	0.07	0.30
Solanum violaceum	2	1	2.86	2.00	0.06	0.23	0.47	0.07	0.30

Wattakaka volubilis	2	1	2.86	2.00	0.06	0.23	0.47	0.07	0.30
Coccinia grandis	1	1	2.86	1.00	0.03	0.23	0.23	0.04	0.26
Dalbergia paniculata	1	1	2.86	1.00	0.03	0.23	0.23	0.04	0.26
Where, n= number of Individuals, Qn= number of qudrats where the species occur, F-Frequency in percentage; A-Abundance; Dn-Density; RF-Relative frequency; RA-Relative abundance; RDn-Relative density; Do-Dominance; R.do-Relative dominance; IVI-Importance Value Index									

4.4.3.3 Herbaceous community

Species Diversity and Richness: A total of 1362 individuals belonging to 80 plant species falling under 66 genera spreading over 24 families were recorded in the present study site of Bodi west hills, Theni district, Tamil Nadu (Table 14). Among the total number of 80 species *Paulopsis imbricata* was represented by highest number of individuals (n = 87) followed by *Cyrtococcum trigonum* (n = 82), *Heteropogon contortus* (n = 70), *Tephrosia purpurea* (n = 65) and *Oropetium thomaeum* (n = 61). Of the 24 families recorded here, Poaceae was represented by maximum number with 25 species followed by Asteraceae (n = 9), Acanthaceae (n = 8), Malvaceae (n = 6) and Amaranthaceae (n = 4). High density values were recorded for *Paulopsis imbricata* (2.49) followed by *Cyrtococcum trigonum* (2.34), *Heteropogon contortus* (2.00), *Tephrosia purpurea* (1.86) and *Oropetium thomaeum* (1.74). The highest relative density was recorded for *Paulopsis imbricata* (6.39) followed by *Cyrtococcum trigonum* (6.02), *Heteropogon contortus* (5.14), *Tephrosia purpurea* (4.77) and *Oropetium thomaeum* (4.48). The Shannon-Weiner diversity observed for herbaceous community in the area is 3.954.

Importance Value Index: The highest IVI values were recorded for *Paulopsis imbricata* (11.67) followed by *Tephrosia purpurea* (10.06), *Heteropogon contortus* (8.91), *Cyrtococcum trigonum* (7.53) and *Bothriochloa pertusa* (6.99).

Table 14: Herbaceous community structure in the study area

Species	***N***	***Qn***	***F***	***A***	***Dn***	***RF***	***RA***	***RD***	***IVI***
Paulopsis imbricata	87	14	40.0	6.21	2.49	5.28	1.55	6.39	11.7
Cyrtococcum trigonum	82	4	11.4	20.5	2.34	1.51	5.13	6.02	7.53
Heteropogon contortus	70	10	28.6	7.00	2.00	3.77	1.75	5.14	8.91

Tephrosia purpurea	65	14	40.0	4.64	1.86	5.28	1.16	4.77	10.1
Oropetium thomaeum	61	4	11.4	15.3	1.74	1.51	3.82	4.48	5.99
Arundinella ciliata	56	5	14.3	11.2	1.60	1.89	2.80	4.11	6.00
Bothriochloa pertusa	49	9	25.7	5.44	1.40	3.40	1.36	3.60	6.99
Tripogon bromoides	41	8	22.9	5.13	1.17	3.02	1.28	3.01	6.03
Oplismenus compositus	40	3	8.57	13.3	1.14	1.13	3.34	2.94	4.07
Garnotia courtallensis	33	4	11.4	8.25	0.94	1.51	2.06	2.42	3.93
Cymbopogon citratus	27	7	20.0	3.86	0.77	2.64	0.97	1.98	4.62
Caralluma umbellata	25	4	11.4	6.25	0.71	1.51	1.56	1.84	3.35
Cymbopogon flexuosus	25	4	11.4	6.25	0.71	1.51	1.56	1.84	3.35
Borreria ocymoides	24	3	8.57	8.00	0.69	1.13	2.00	1.76	2.89
Achyranthes aspera	23	7	20.0	3.29	0.66	2.64	0.82	1.69	4.33
Anisochilus carnosus	23	2	5.71	11.5	0.66	0.75	2.88	1.69	2.44
Brachiaria ramosa	21	4	11.4	5.25	0.60	1.51	1.31	1.54	3.05
Chloris dolichostachya	21	5	14.3	4.20	0.60	1.89	1.05	1.54	3.43
Cynodon barberii	21	6	17.1	3.50	0.60	2.26	0.88	1.54	3.81
Peristrophe bicalyculata	20	6	17.1	3.33	0.57	2.26	0.83	1.47	3.73
Sida cordata	20	5	14.3	4.00	0.57	1.89	1.00	1.47	3.36
Tribulus terrestris	20	3	8.57	6.67	0.57	1.13	1.67	1.47	2.60
Evolvulus alsinoides	19	5	14.3	3.80	0.54	1.89	0.95	1.40	3.28
Scoparia dulcis	19	4	11.4	4.75	0.54	1.51	1.19	1.40	2.90
Polycarpaea corymbosa	18	3	8.57	6.00	0.51	1.13	1.50	1.32	2.45
Aristida funiculata	17	5	14.3	3.40	0.49	1.89	0.85	1.25	3.14
Conyza stricta	17	3	8.57	5.67	0.49	1.13	1.42	1.25	2.38
Ocimum canum	17	2	5.71	8.50	0.49	0.75	2.13	1.25	2.00
Psilotrichum elliottii	17	6	17.1	2.83	0.49	2.26	0.71	1.25	3.51
Eragrostis plumosa	16	3	8.57	5.33	0.46	1.13	1.33	1.17	2.31
Kalanchoe laciniata	15	2	5.71	7.50	0.43	0.75	1.88	1.10	1.86
Pavonia procumbens	15	5	14.3	3.00	0.43	1.89	0.75	1.10	2.99
Zenkaria elegans	15	3	8.57	5.00	0.43	1.13	1.25	1.10	2.23
Enteropogon monostachyas	14	3	8.57	4.67	0.40	1.13	1.17	1.03	2.16
Eragrostis viscosa	14	3	8.57	4.67	0.40	1.13	1.17	1.03	2.16
Ruelia patula	14	2	5.71	7.00	0.40	0.75	1.75	1.03	1.78
Blepharis repens	13	4	11.4	3.25	0.37	1.51	0.81	0.95	2.46
Justicia tranquebariensis	13	4	11.4	3.25	0.37	1.51	0.81	0.95	2.46
Blepharis molluginifolia	12	3	8.57	4.00	0.34	1.13	1.00	0.88	2.01
Hibiscus micranthus	12	4	11.4	3.00	0.34	1.51	0.75	0.88	2.39
Sida acuta	12	3	8.57	4.00	0.34	1.13	1.00	0.88	2.01

Apluda mutica	11	3	8.57	3.67	0.31	1.13	0.92	0.81	1.94
Aristida hystrix	11	3	8.57	3.67	0.31	1.13	0.92	0.81	1.94
Caralluma attenuata	11	3	8.57	3.67	0.31	1.13	0.92	0.81	1.94
Cyperus sp.	11	1	2.86	11.0	0.31	0.38	2.75	0.81	1.19
Leucas aspera	11	1	2.86	11.0	0.31	0.38	2.75	0.81	1.19
Aerva lanata	10	4	11.4	2.50	0.29	1.51	0.63	0.73	2.24
Boerhavia diffusa	9	5	14.3	1.80	0.26	1.89	0.45	0.66	2.55
Pupalia lappacea	9	3	8.57	3.00	0.26	1.13	0.75	0.66	1.79
Lantana wightiana	8	1	2.86	8.00	0.23	0.38	2.00	0.59	0.96
Synedrella nodiflora	8	1	2.86	8.00	0.23	0.38	2.00	0.59	0.96
Borreria hispida	7	2	5.71	3.50	0.20	0.75	0.88	0.51	1.27
Cyperus rotundus	7	1	2.86	7.00	0.20	0.38	1.75	0.51	0.89
Justicia simplex	7	2	5.71	3.50	0.20	0.75	0.88	0.51	1.27
Sida cordifolia	7	3	8.57	2.33	0.20	1.13	0.58	0.51	1.65
Tridax procumbens	7	3	8.57	2.33	0.20	1.13	0.58	0.51	1.65
Aristida adscensianis	6	1	2.86	6.00	0.17	0.38	1.50	0.44	0.82
Parthenium hysterophorus	6	3	8.57	2.00	0.17	1.13	0.50	0.44	1.57
Themeda triandra	6	1	2.86	6.00	0.17	0.38	1.50	0.44	0.82
Waltheria indica	6	4	11.4	1.50	0.17	1.51	0.38	0.44	1.95
Abutilon persicum	5	2	5.71	2.50	0.14	0.75	0.63	0.37	1.12
Sigesbeckia orientalis	5	1	2.86	5.00	0.14	0.38	1.25	0.37	0.74
Cassia occidentalis	4	2	5.71	2.00	0.11	0.75	0.50	0.29	1.05
Commelina longifolia	4	1	2.86	4.00	0.11	0.38	1.00	0.29	0.67
Eriocaulon truncatum	4	1	2.86	4.00	0.11	0.38	1.00	0.29	0.67
Hemedesmus indicus	4	1	2.86	4.00	0.11	0.38	1.00	0.29	0.67
Micrargeria wightii	4	1	2.86	4.00	0.11	0.38	1.00	0.28	0.66
Mollugo pentaphylla	4	1	2.86	4.00	0.11	0.38	1.00	0.29	0.67
Triumfetta pentandra	4	1	2.86	4.00	0.11	0.38	1.00	0.29	0.67
Commelina benghalensis	3	1	2.86	3.00	0.09	0.38	0.75	0.22	0.60
Garnotia elata	3	1	2.86	3.00	0.09	0.38	0.75	0.22	0.60
Andrographis alata	2	1	2.86	2.00	0.06	0.38	0.50	0.15	0.52
Biophytum sensitivum	2	1	2.86	2.00	0.06	0.38	0.50	0.15	0.52
Conyza leucantha	2	1	2.86	2.00	0.06	0.38	0.50	0.15	0.52
Corchorus tridens	2	1	2.86	2.00	0.06	0.38	0.50	0.15	0.52
Dactyloctenium aegyptium	2	1	2.86	2.00	0.06	0.38	0.50	0.15	0.52
Enneapogon schimperianus	2	1	2.86	2.00	0.06	0.38	0.50	0.15	0.52
Phyllocephalum sp.	2	1	2.86	2.00	0.06	0.38	0.50	0.15	0.52
Vernonia cinerea	2	1	2.86	2.00	0.06	0.38	0.50	0.15	0.52

Socnhous oleraceous	1	1	2.86	1.00	0.03	0.38	0.25	0.07	0.45
Where, n= number of Individuals, Qn= number of qudrats where the species occur, F-Frequency in percentage; A-Abundance; Dn-Density; RF-Relative frequency; RA-Relative abundance; RDn-Relative density; Do-Dominance; R.do-Relative dominance; IVI-Importance Value Index									

4.4.4 Faunal Analysis

The total vertebrate species observed in and around the project location during the survey were 26 species of mammals (Table 15), 27 species of reptiles (Table 16), 14 species of amphibians (Table 17) and 78 species of birds (Appendix 7). We have also incorporated information available in the working plan for Theni forest division (Malik, 2004) on the presence of avian and mammalian species. In total 49 species of mammals, and 137 species of birds are recorded from the area.

Considering the known distribution of each species of mammals a total of 27 species of mammals (excluding small rodents and species belonging to the Order Chiroptera) are expected to be present in the study area. During the survey only few species were encountered / sighted namely bonnet macaque, Asian palm civet and black-nape hare. The giant flying squirrel could be heard. No mammal species were sighted within 1 km radial distance from the portal. Nevertheless, droppings of jackal, Asian palm civet, small Indian civet, black nape hare, sloth bear, jungle cat, common mongoose and elephants could be seen. The area is said to be a potential elephant habitat (INO sources). A population of 28-30 elephants is said to be present in the entire Theni division, of which a few occasionally visit the study area. Nevertheless, elephant and sloth bear droppings seen there were very old and rare in number, revealing that these species use the area only very occasionally. Other species recorded are generalist species that are widely distributed in the country and the fewer number of scats of the species in the area reflects that the abundance of those species is low. We interviewed local people within a 5 km radius of the INO site. They reported occurrence of few additional species, which, however, were highly restricted to higher elevation. Elephant and dhole (Wild Dog) are two important species that were reported; but they are seen in low density and rare.. Dholes are restricted to higher altitude towards north-west of the site, and are rarely sighted.

Among the compiled check list of mammals, 5 species are found under the IUCN Category "endangered", 7 species "vulnerable" and 7 species of "near threatened". Recent reports by Easa et al (2010) have identified several potential habitats for endangered Nilgiri Tahr *(Nilgiritragus hylocrius)* in the Theni Forest division. They have estimated 320-360 numbers of tahr in the forest division. However, they are distributed apparently away from the portal site. Based on our survey Pallid Harrier (*Circus macrourus*) is the only species of bird found in the area falling in the "near threatened" category of IUCN (Appendix 7). However, according to Malik, (2004) in the whole Theni forest division, there are 10 species of "near threatened", two species "critically endangered", and two species of "endangered" birds. In total the bird list consists of 21 species of endemic birds of southern India, and three species are endemic to Western Ghats. Similarly the reptiles of the area consist of one "endangered" species (Indian Rock Python (*Python molurus molurus*)) and three "vulnerable". Three reptilian species and one amphibian species recorded are endemic to Western Ghats.

A total of 59 species spreading over 5 families of butterflies could be recorded in the proposed study area (Appendix 8). Of these, the family Nymphalidae is the dominant one with 24 species followed by Pieridae with 17 species. Of the species listed here certain butterflies come under threatened and endemic category. Common Mime, Crimson Rose and Common Pierrot are protected under schedule - I of Wildlife Protection Act 1972. Common Gull is covered under scheduled – II and Common Crow under schedule - IV of the Act. The species like Double-banded crow, Blue Mormon, Crimson rose and Common banded peacock are endemic species, the distributions of which are restricted to the Peninsular India. Of these Blue Mormon is endemic to Western Ghats.

Table 15: Mammals recorded in the study area

	English name	***Zoological name***	***IUCN status***
1	Asian palm civet	*Paradoxurus hermophroditus*	LC
2	Bengal Fox *	*Vulpes bengalensis*	LC
3	Black Rat *	*Rattus rattus*	LC
4	Blackbuck *	*Antilope cervicapra*	NT

5	Black-naped hare	*Lepus nigricollis*	LC
6	Bonnet macaque	*Macaca radiata*	LC
7	Chital	*Axis axis*	LC
8	Common Giant flying squirrel	*Petaurista petaurista*	LC
9	Common mongoose	*Herpestes edwardsi*	LC
10	Common Palm Squirrel *	*Funambulus palmarum*	LC
11	Coromandel Pipistrelle *	*Pipistrellus coromandra*	LC
12	Dhole	*Cuon alpinus*	EN
13	Elephant	*Elephas maximus*	EN
14	Eurasian Otter *	*Lutra lutra*	NT
15	Four-horned Antelope *	*Tetracerus quadricornis*	VU
16	Gaur	*Bos gaurus*	VU
17	Golden Jackal *	*Canis aureus*	LC
18	Greater Bandicoot Rat *	*Bandicota indica*	LC
19	Hanuman langur	*Semnopithecus entellus*	LC
20	House Shrew*	*Suncus murinus*	LC
21	Indian bison *	*Bos gaurus*	VU
22	Indian Chevrotain *	*Moschiola indica*	LC
23	Indian crested Porcupine	*Hystrix indica*	LC
24	Indian Flying Fox*	*Pteropus giganteus*	LC
25	Indian Gerbil *	*Tatera indica*	LC
26	Indian Pangolin	*Manis crassicaudata*	NT
27	Indian wild pig	*Sus scrofa*	LC
28	Jungle cat	*Felis chaus*	LC
29	Leopard	*Panthera pardus*	NT
30	Leopard cat	*Prionalilurus bengalensis*	LC
31	Lion-tailed Macaque *#	*Macaca silenus*	EN
32	Little Indian Field Mouse *	*Mus booduga*	LC
33	Long-eared Hedgehog *	*Hemiechinus auritus*	LC
34	Madras Treeshrew *	*Anathana ellioti*	LC
35	Malabar giant squirrel#	*Ratufa indica*	NT
36	Nilgiri Langur	*Semnopithecus johnii*	VU
37	Nilgiri Marten *#	*Martes gwatkinsii*	VU
38	Nilgiri Tahr *	*Nilgiritragus hylocrius*	EN
39	Ratel or Honey Badger *	*Mellivora capensis*	LC
40	Sambar	*Rusa unicolor*	VU
41	Slender loris	*Loris lydekkerianus*	LC
42	Sloth bear	*Melursus ursinus*	VU

43	Small Indian civet	*Viverricula indica*	LC
44	Southern Red Muntjac	*Muntiacus muntjak*	LC
45	Sri Lankan Giant Squirrel *	*Ratufa macroura*	NT
46	Striped hyena *	*Hyaena hyaena*	NT
47	Stripe-necked Mongoose *	*Herpestes vitticollis*	LC
48	Tiger *	*Panthera tigris*	EN
49	White spotted Chevrotain	*Tragulus meminna*	LC
EN: Endangered; VU: Vulnerable; NT: Near threatened; LC: Least concern. *Not encountered during the survey, but are reported by Malik (2004). # Endemic to Western Ghats (Bava et al, 2007)			

Table 16: Reptiles recorded in the study area

	English name	***Zoological name***	***IUCN status***
1	Asian House Gecko	*Hemidactylus frenatus*	LR
2	Bark Gecko	*Hemidactylus leschenaultii*	LR
3	Beddome's Grass Skink	*Mubuya beddomei*	LR
4	Bengal Monitor Lizard	*Varanus bengalensis*	VU
5	Bronze Grass Skink	*Mabuya macularia*	LR
6	Brook's House Gecko	*Hemidactylus brookii*	LR
7	Common Cat Snake	*Boiga trigonota*	LR
8	Common Sand Boa	*Gongylophis conicus*	LR
9	Common Vine Snake	*Ahaetulla nasuta*	LR
10	Common Wolf Snake	*Lycodon aulicus*	LR
11	Fan throated Lizard	*Sitanan ponticeriana*	LR
12	Green forest Lizard	*Calotes calotes*	LR
13	Horseshoe Pit Viper	*Trimeresurus strigatus*	LR
14	Indian garden Lizard	*Calotes versicolor*	LR
15	Indian Rat Snake	*Ptyas mucosa*	LR
16	Indian Rock Python	*Python molurus molurus*	EN
17	Keeled Grass Skink	*Mabuya carinata*	LR
18	Large-scaled Pit Viper	*Trimeresurus macrolepis*	LR
19	Malabar Pit Viper#	*Trimeresurus malabaricus*	VU
20	Red Sand Boa	*Eryx johnii*	LR
21	Russell's Viper	*Daboia russelii*	LR
22	Saw-scaled Viper	*Echis carinatus*	LR
23	South Asian Chamaeleon	*Chamaeleo zeylanicus*	VU
24	South Indian Rock Agama#	*Psammophilus dorsalis*	LR
25	Spectacled Cobra	*Naja naja*	LR
26	Termite-hill Gecko	*Hemidactylus triedrus*	LR
27	Three-lined Grass Skink#	*Mubuya trivittata*	LR
#Endemic to Western Ghats. LR: Low Risk; VU: Vulnerable; EN: Endangered			

Table 17: Amphibians recorded in the study area			
English name		***Scientific name***	***IUCN Status***
1	Beddome's Leaping Frog#	*Indirana beddomei*	LC
2	Bronzed Frog	*Sylvirana temporalis*	LC
3	Common Indian Toad	*Duttaphrynus melanostictus*	LC
4	Common Tree Frog	*Polypedatus maculates*	LC
5	Cricket Frog	*Fejervarya limnocharis*	LC
6	Ferguson's Toad	*Bufo scaber*	LC
7	Indian Bull Frog	*Hoplobatrachus tigrinus*	LC
8	Indian Burrowing Frog	*Sphaerotheca breviceps*	LC
9	Indian Painted Frog	*Kaloula taprobanica*	LC
10	Indian Pond or Green Frog	*Euphlyctis hexadactylus*	LC
11	Lessor or Marbled Balloon Frog	*Uperodon systoma*	LC
12	Ornate Narrow-mouthed Frog	*Microhyla ornateornata*	LC
13	Red Narrow-mouthed Frog	*Microhyla rubra*	LC
14	Water Skipper or Skipper Frog	*Euphlyctis cyanophlyctis*	LC
# Endemic to Western Ghats. LC=Least Concern			

5 ECOLOGICAL IMPACTS

Impact Assessment, taking into account the baseline data generated as above and the project details, is a necessary process in developing appropriate ecological management strategy for a relatively ecologically benign execution of the project. Such an exercise helps in identifying mitigatory measures and ecologically sustainable or informed tradeoffs. It is one of the foremost tools used to cut down ecological / environmental degradation associated with human activities. The process at the foremost involves listing out, in a more or less quantified manner, the major factors which could restrain the natural processes of the ecosystem that later may lead to irrevocable loss of accounted and unaccounted ecological good and services, even collapse of the system or loss of species or ecosystems.

5.1 KEY CONCERNS

In the view of the earlier report on the predicted major impacts of the project at Masinagudi by Azeez et al., (2007), the details gathered from the INO officials on the present project activities and looking at similar activities done elsewhere we have listed out the major impacts of the proposed project to the local ecosystems. These concerns are given below in an areal, chronological and in a functional perspective.

5.1.1 Areal/ spatial extent

In general, the impacts of activities such as INO construction at a location will be highest at the site near the portal, with the impact gradually receding according to distance. However, exceptions to this presumption are several and that depend on the specifity of the project activity. In the case of the INO, mainly being a construction / excavation activity with later operational actvities limited largly to underground caverns; it is not expected to alter any major environmental flows that could have its effect at a distant elsewhere. This statement is made here disregarding any geological implications, which do not come under the purview of the present

report. The project is also not known to have potential to release liquid or gaseous emissions that are seriously noxious and can spread wide with any environmental significance.

From an areal perspective the gravity of the impact will be highest at the portal and its immediate vicinity. The portal is evidently the centre of activity since most of the other works are going to happen underground, but via the portal. The impacts are expected to gradually reduce as the distance increases. Similarly, from a temporal point of view the impacts are likely to be higher during the phase of construction than during the operation.

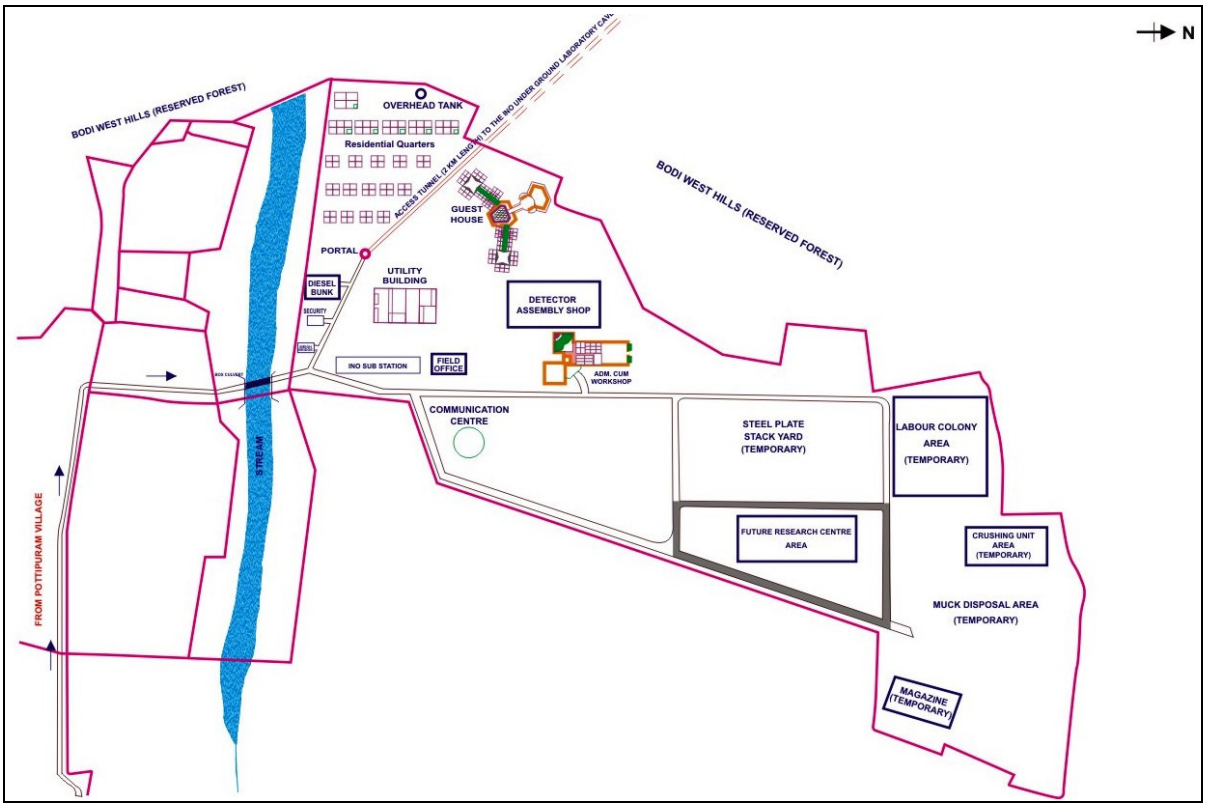

Figure 11: The surface facilities proposed at INO project area, Bodi west hills, Tamil Nadu

In the case of INO it is reported that surface constructions (Figure 11) near by the portal will extend to an area of 23 ha of government *puramboke land.* Therfore the impacts, the major ecological purturbations or changes will be concentrated at this area during both the construction and the operation phase of the project. However, collateral impacts are likely in and around this

23 ha land as mentioned else where in this report. Similarly, during the operation phase also the impacts will be high at the portal area.

5.1.2 Impacts during construction phase

As mentioned earlier, the work during the construction phase of the INO includes the construction of the underground laboratory and the associated structures including roads and other transportation means. The construction phase in general involves a plethora of activities such as clearing of the vegetation, excavation, transportation and labor activities.

The major works, likely to have impact on the ecological setup of the area are as follows.

- Clearing the construction site
- Excavation and blasting during excavation and clearing routes
- Erecting structures for the project
- Sourcing of materials
- Vehicular movement and movement of men and materials
- Vibrations, smoke, noise and operation of earthmoving machinery
- Temporary human inhabitations
- Storage of muck / debris, and transport and disposal of excavated overburden, debris and muck
- Disposal of spills of wastes, fuels and lubricants

5.1.2.1 Clearing the vegetation at the project site

Clearing vegetation for the INO construction will be restricted to the relatively sparsely vegetated *puramboke* land (S.No. 4/1). The vegetation in the area is scrub jungle and mixed dry deciduous type. Several plants occupying the area will get removed. Similar is the case with several small faunal species that are likely to be residing there. However, no species; either flora or fauna, recorded there so far is restricted to the *puramboke* land. Further, from our study we could not find any species which will lose an important part of its habitat because of this clearing.

The major species that are seen in the area and could get effected are *Abutilon indicum, A. hirtum, Acacia chundra, A. nilotica, A. mellifera, A. torta, Acalypha fruticosa, A. indica, Achyranthes aspera, Aerva lanata, Alloteropsis cimcinna, Anisochilus carnosus, A. scaber, Anisomeles indica, A. malabarica, Apluda mutica, Aristida adscensionis, A. funiculata, A. hystrix, Azadirachta indica, Barleria acuminata, B. prionitis, B. tomentosa, Blepharis maderaspatensis, B. molluginifolia, Bothriochloa pertusa, Capparis sepiaria, Caralluma attenuata, C. umbellata, Carissa carandas, C. spinarum, Cassia auriculata, C. occidentalis, Chloris barbata, C. dolichostachya, Eragrostis atrovirens, E. viscosa, Euphorbia antiquorum, E. hirta, E. thymifolia, Fiucs microcarpa, Fluggea leucopyrus, Glycosmis mauritiana, G. pentaphylla, Gmelina asiatica, Grewia hirsuta, G. villosa, Gyrocarpus americanus, Justicia betonica, J. simplex, Kleinia grandiflora, Lantana wightiana, Leucas aspera, L. biflora, Maytenus ovata, Mollugo cerviana, M. nudicaulis, M. pentaphylla, Monothecium aristatum, Mundulia sericea, Nothosaerva brachiata, Oldenlandia biflora, O. corymbosa, O. umbellata, oxalis corniculata, Passiflora foetida, Pavonia procumbens, P. zeylanica, Perotis indica, Phyllanthus amarus, P. maderaspatensis, Polycarpaea corymbosa, Prosopis juliflora, Pseudarthria viscida, Pterolobium hexapetalum, Randia dumetorum, Rhynchosia minima, Ruelia patula, Salacia reticulata, Sansivieria roxburghiana, Scutia myrtina, Secamone emitica, Sida acuta, S. cordata, Solanum pubescens, Strobilanthes consanguinea, S. cuspidatus, Tarenna asiatica, Tephrosia purpurea, T. villosa, Toddalia asiatica, Tylophora indica, Vernonia cinerea, Vicoa indica, Waltheria indica* and *Ziziphus oenoplia*. Most of these species are very commonly distributed in the area or elsewhere.

5.1.2.2 Erecting structures required for the project

The major structures that are to be built for the project are listed in the Table 1; over ground office and residences and underground caverns and tunnels. The impacts during the construction phase are mostly associated with digging the 2 km long nearly horizontal under ground tunnel and caverns. The land use changes associated with building the “over ground” structures, roads, the muck dumping yard and the crusher locations also will have impacts on the local ecological setup. As noted above the over ground structures are to be erected in the government *puramboke*

lands (New Indian express, 2010; INO, 2010) covered by scrub jungle and dry mixed deciduous forest. Hence, the impact due to erecting the structures is relatively low and will be largly limited to the 23 ha. As reported earlier, the area is not frequented by larger wild species such as elephants or dholes.

The project location is reported to be situated in the Seismic Zone 2 and since the structures are designed appropriately for the zone (following National Disaster Management Authority and Bureau of Indian Standards guidelines), any natural disasters getting synergized by the built up structures would be brought down to a great extend.

5.1.2.3 Muck / debris

The waste produced during the processes of excavation will be in the form of muck, boulders and other debris, about 2.25-lakh m^3 the disposal of which will require a large area. Carelessly isposed debris / muck are likely to add on to siltation downstream along with the run off in the monsoon. Measures should be taken up in order to utilise maximum quantity of debris for construction at the earliest and measures need to be taken to avoid dust and suspended matter arising in the air due to wind and other natural forces.

The muck / debris have to be collected and stored in an appropriate location. The INO has identified site for muck yard (for temporary storage, Figure 11). They also propose to utilize 10 to 15% of the debris to meet own requirements. Some of the issues associated with muck / debris disposal are listed below.

- The muck storage requires a large area,
- If exposed to sun, wind and other natural elements and human activities muck adds on to
    - the suspended particulate matter (SPM) in the ambient atmosphere
    - high suspended load in the run off during monsoon,
    - with the runoff water, the muck will add on to the silt load; that may lead to the release of trace metals to the environment gradually.

- The dumping yards are aesthetically unpleasant in the overall environmental set up of the area. It normally do not offer chance for any plant growth and may become a haven for vermin species
- It leads to increase in vehicle movement to transport the muck from the point of generation to that of disposal and / or storage

5.1.2.4 Sourcing the material requirements and storage

Large quantities of materials are required during the construction phase. It includes sand/stones, steel and cement. Transport of construction materials such as stone is expected to be lesser in the case of this project, since they propose to utilise excavated materials / debris as much as possible for the construction. The debris generated from the blasting can be utilized for laying roads, buildings, residences and other structures. This will reduce sourcing the material required during construction from elsewhere leading to reduction in the project cost as well as pressure / impact on the environment.

During the construction phase a temporary stockyard for construction material (mainly steel plates for the detector), will be created (Figure 11). The yard will be located within the revenue *puramboke* land (S.No 4/1) at the Pottipuram village.

About 40KLD of water is required during the construction for diverse activities including water spraying to reduce dust rising from the muck / debris. The water during this period will be brought in using tankers. INO has committed to source water from elsewhere and not from the local ground water resources or local seasonal streams.

5.1.2.5 Transport of materials, machinery, and vehicular and labor movement

Transport of construction materials (~52 000 M tons) to the project site will be via a 1.5 km long new road to be built for the purpose (Figure 12). A box culvert will be constructed across the small stream, at the entrance to the INO site. Thus, the road alignment would take care that the road does not impair water flow to the stream.

About 27 numbers of earthmovers, dumpers, trucks, road rollers, jeeps and other vehicles will be required for the job (Table 18). These all are likely to produce notable changes in the ambient noise levels and ambient atmospheric suspended matter level.

Table 18: Machinery that will be used during construction		
	Machinery	Quantity
1	Bulldozer/tipper	10
2	Jack Hammer	10
3	Road Rollers	1
4	Jeeps/Lorries/vans	6

Transport and such activities require a high number of workmen/labour, both skilled and semi-skilled. Engineers and technicians will be involved in the construction work. The total number of workers to be engaged is 20 skilled, 20 semiskilled and 50 unskilled during the first year (Table 4). The number will remain more or less the same during the later years of construction. Presence of workers will require the INO to identify means to meet their personal and primary requirements, and management of wastes appropriately.

5.1.2.6 Blasting to excavate the tunnels and cavern

The laboratory and other under ground structures are to be constructed in hard charnockite rock. Blasting hard rock produces tremendous sound, flash and vibrations. The sound and vibrations from the blast may cause mild disruption to the normal activities, such as routine local movements, of wildlife if any. Serious vibrations, if any, are also likely to effect den-dwelling animals, which however due to hundreds of meters of rock and soil would be dampened considerably as discussed below.

Blasting is known to cause vibrations and serious damage to close-by landscape and may have impact on the geological make-up / formation in the surroundings, a subject not under the scope of the present report. Nevertheless, avoiding or minimizing blasting by resorting to other methods, may be better to reduce the impacts. During the field survey, we have come across the presence of three commercial functional mines in the region, using heavy blasters, which cause sound and dust pollution.

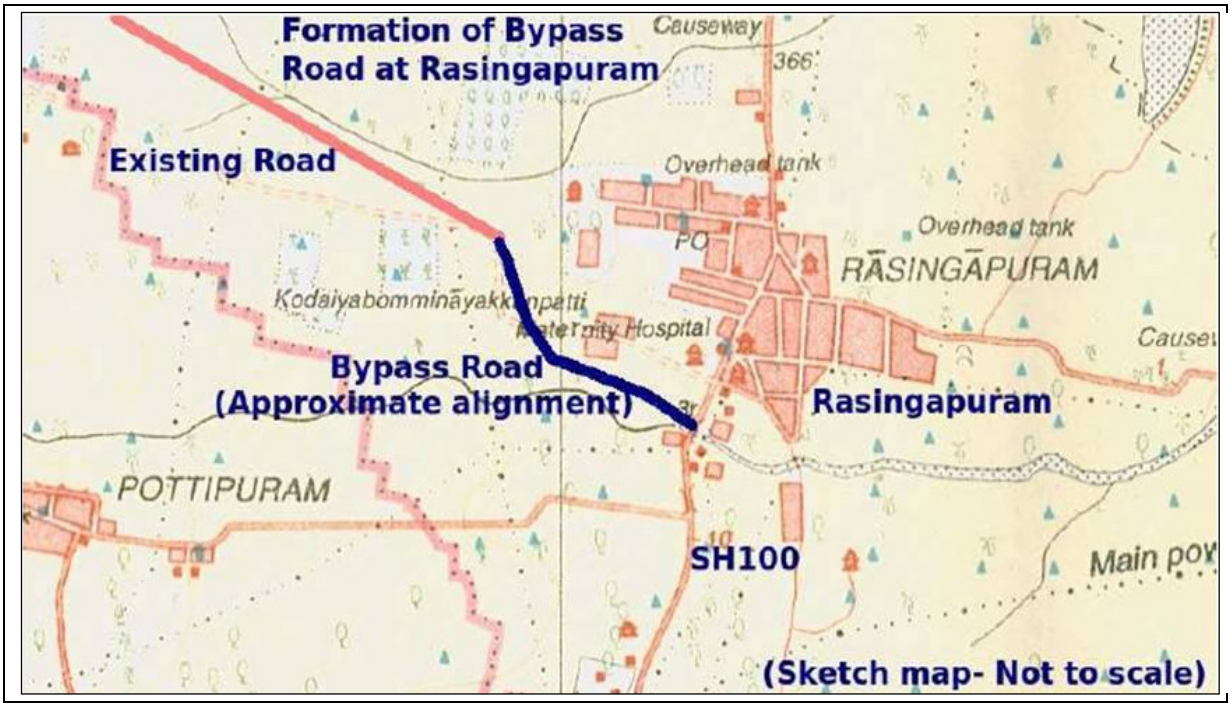

Figure 12: Proposed bypass connecting the existing road to the State Highway 100

Ground vibration: All the major components of the project are located underground. Blasting to be carried out for excavation of caverns and associated components, is likely to cause vibrations perceivable at the surface. As the excavation of tunnel progresses deeper underground the estimated vibration effective at the surface is likely to reduce.

Similarly based on the blast vibration study carried out for an underground Hydro Electric Project located in the Pykara nearby the area originally proposed for INO (Masinagudi), was found to be reduced to a more or less negligible level of 0.68 mm/s, because of the large overburden (>1000 m) lying over the work site.

Dust, gases and noise: Explosion used in rock excavation is another major source of dust and noise. Storage of explosives is an issue of concern in terms of risks of fire, explosion, and release of noxious gas pollutants. The noise arising from explosives while blasting could be grouped as i) continuous wide band noise, ii) continuous narrow band noise, iii) impact noise, iv) repetitive impact noise and v) intermittent noise each having wide ranging impacts on animals and

environment. It may be possible to reduce the noise levels in many in-house activities such as in workshops related with the project execution. Nevertheless, it is less practical to reduce noise levels in the construction and excavation sites. After the tunnel work has progressed considerably, the noise reaching outside the tunnel will be considerably muffled.

High levels of noise can disturb birds and other animals frequenting the sites. Animals can perceive frequencies that are out of range for human auditory system. They are known to be highly sensitive to certain frequency ranges, even infra or ulstrasonic levels. They suffer stress, and undergo metabolic and behavioural changes. Many of them leave the site of high noise level. Birds are also seen to discard nests, eggs and even fledglings in response to certain abrupt noise levels. The sound and vibrations may cause disruption to the normal activities such as local and seasonal migration and denning. However, in the case of the present locations, not many animals could be seen close to the project site and the impact is likely to be low.

5.1.2.7 Smoke and noise from machinery

It is reported that during the construction phase, emission from about 50 sources including earthmoving machinery, material handling and transport vehicles and light vehicles are expected in the area. Smoke from the automobiles is an important source of air pollutants including particulates. They are also the source of fugitive emissions of chiefly Suspended Particulate Matter (SPM), SO^2, NO_x, CO and partially burnt hydrocarbons. Thus, change in the ambient air quality is likely in the area, although depending on the machinery and vehicle conditions /activities.

Operation of large earth-moving machinery may increase the ambient noise level. The machinery will produce sound, vibrations and noise, which will be a cacophony for wild species. Many of the wild species are sensitive to the unfamiliar sounds and are affected due to them.As mentioned earlier shy birds may also leave their nesting site and even discard their fledglings in response to abrupt increase in noise levels. Many species such as bats and elephants can hear sounds, which are not audible to human ears. This may affect their local and seasonal migration. However, the reduction in noise level is relatively impractical in sites such as that of construction and

excavation; but the usage of well-maintained machinery may help in the reduction of the same largely.

5.1.2.8 Workmen inhabitation during the construction phase

The construction work for the project would involve more than 100 strong workforce. The labourers / workers and their families are likely to reside in the worksite and exploit local vegetation for fuel-wood. If left uncontrolled, this will cause tremendous pressure on the ecosystem. Though they are temporary residents, they may bring livestock and poultry; thus, causing increased pressure on the environment. Discharge of sewage and other waste materials from the human settlement to the near-by land and water resources is an issue to be managed. Similarly, burning waste materials from the residential area also adds the air pollution hazard of the area.

5.1.2.9 Impact matrix for the construction phase

Taking note of the actvities involved in INO establishment and operation an attempt was made to develop an impact evaluation matrix. According to the pattern of grading the least impact is given a score 1. The grades increase with the seriousness of the impact up to 10, which indicates very severe impact. The overall impacts of activities during construction phase could be summarized as given below (Table 19). Although in developing these matrices worst-case scenarios were assumed taking account of the variations in ecological setup of the area, the exercise shows that during both the construction and operation phase the possible impacts are low.

5.1.3 Impacts during the operation phase

During the operation phase the impacts of the underground laboratory is limited, except in the case of release of gas, although the gas used in the laboratory, on its own, is not known to be very toxic for short-term exposures. However, it is reported that the gas [Freon (R 134a; GWP = 1300), Isobutane; GWP = 0.001, and SF_6; GWP- 23900; for comparison GWP of CO_2 = 1 see IPCC, 2001] filled in the RPC chamber will be released after several recycling. INO is exploring

appropriate techniques to recycle the exhaust gas mixture (Appendix 1) having global warming potentials rathen than releasing them to the atmosphere after dilution.

Table 19: Impact matrix of perturbations likely from the INO during the construction phase

Activities		***Damage to***					
		F	***M***	***B***	***R***	***A***	***BF***
1	Clearing the construction site	6	3	4	5	5	5
2	Blasting during excavation and clearing routes	2	3	3	4	4	4
3	Excavation	2	1	3	4	4	2
4	Erecting structures for the project	3	2	3	4	4	2
5	Sourcing of materials	2	1	2	1	1	2
6	Vehicular and labor movement	2	2	2	3	3	3
7	Vibrations, smoke, noise	2	2	1	2	2	2
8	Temporary human inhabitation	4	3	4	3	3	4
9	Storage of muck / debris	4	4	1	2	2	2
10	Transport and disposal of excavated overburden, debris and muck	4	4	2	1	1	1
11	Disposal of spills of wastes, fuels and lubricants	3	3	1	1	1	1
10	Movement of men and materials	3	4	3	3	3	2
11	Operation of earthmoving machinery	2	3	3	5	5	4

Note: Impacts / damages graded according to the severity from 1 to 10, 1 indicating the least impact and 10 the highest.
M= Mammals, B= Birds, R= Reptiles, A= Amphibians and BF = Butterflies

The noise, sound and light pollution from the machineries during the operation phase, especially in the over ground part of the INO cannot be neglected. Similarly, during the demolition of the temporary structures built during construction the noise expected also has to be checked.

The impact of INO during the operation phase can be categorised into i) movement of staff involved in the day-to-day operation of the facility, ii) waste generated during operation and maintenance of the facility, iii) scholars and researchers visiting the facility in single, small or large numbers and iv) impacts due to residences and other support facilities. The brief impact matrix for the operation phase is given below (Table 20).

Table 20: Impacts on the biological components in the area during the operation phase						
Factors	***Impacts on***					
	F	***M***	***B***	***R***	***A***	***BF***
People's movement and activities	2	2	3	3	3	2
Residences and offices	2	2	2	2	2	2
Sourcing water and other materials for laboratories and residences	1	1	1	1	1	1
Underground laboratories	1	1	1	1	1	1
Power transmission	1	1	1	1	1	1
Noise pollution	1	3	3	2	2	2
Air / water pollution	1	1	1	1	1	1
Solid wastes	2	3	1	1	1	2
Vehicle / machinery maintanace	2	2	1	2	2	1
Note: Impacts / damages graded according to the severity from 1 to 10, 1 indicating the least impact and 10 the highest. F = Flora, M= Mammals, B= Birds, R= Reptiles, A= Amphibians and BF = Butterflies						

6 ECOLOGICAL MANAGEMENT PLAN

As mentioned in the earlier chapter the proposed INO project is expected to cause some changes to the ecological setup of the area. Since, the project does not involve large scale overground changes, large scale increase in population in the area, and gaseous / liquid emissions the impacts / perturbations arising from the project would not be of large scale either in spatial or temporal scale. Nevertheless, the impacts need to be examined from a management / mitigators point of view. Attempts have to be made to reduce the intensity of such impacts by adopting certain control measures. This part of the report will be discussing suggested means of mitigation in view of the possible impacts discussed earlier.

6.1 LAND USE CHANGES

The land use changes associated with building and construction activities has to be checked for its impacts on the surrounding environment. As mentioned earlier, major portion of the project is going to be constructed in the underground. Hence, the land use changes on the earth surface will be very less. Only the part of the land earmarked for surface facilities, the 23 ha of government *puramboke* land in which the portal entry of the project is also located, will be cleared of the vegeation, converted to buildings, temporary houses and stockyards.

Constructions of other components of the project do not cause any changes in landuse as they are built deep below the ground. As noted earlier not much large wild animals frequent in the area and since the land use changes are limited to 4 ha of the 23 ha aquired for the INO, the project would not have much implcations on wild animals and flora. As mentioned below the development of green belt may improve habitat for smaller animals and birds.

6.2 WILDLIFE USAGE

During our survey we have seen only very few old decomposing elephant dungs near the portal location. Nevertheless, as a precautionary measure the INO officials involved in construction,

contractors and workers need to be made aware of the need to avert disturbance to wild species. The areas that are likely to be visited by the animals could be identified and activities there to be limited to seasons when the animals are unlikely to go through the area.

6.3 NOISE AND VIBRATION

All methods of excavating tunnels generate noise. Tunnel boring machine produces persistent and irritating noise of high frequency. Blasting generates noise pulses of high volume, which however, can be reduced to almost a "thud" by properly designing the blast especially in the initial 300 meters of excavation. Beyond about 300m inside the underground tunnel blasting will not produce any definite and serious noise, perceptible outside the tunnel.

The noise and vibration during the construction and operation phase has to be minimized using well maintained machineries and vehicles. If essential, blasting may be limited to the bare minimum and appropriately designed to muffle the noise and unwanted reverberating vibrations especially at the exposed areas. However, inside the tunnel blasting deep with delayed / sequential detonation and overburden of charnockite and soil above, it is expected that the sound and the vibrations would be considerably dampened. The number of blasts could be minimized and temporally spaced out. Also, advanced drilling and blasting techniques may be adopted which would save time, resources and protect environment as well. Blasting and related activities may be avoided near by the open area during dawn, dusk and night. Well planned faster execution of construction phase would reduce the impact on environment very much.

INO may undertake ground vibration monitoring study during actual execution of the project along with other rock mechanics and instrumentation studies. The ground vibration may be measured continuously during blasting operations for all the major components of the project. Appropriate blasting pattern and modern blasting techniques based on the actual site geology, may be adopted such that vibration could be brought to the minimum. Good for the project, the present site is not of much importance from the point of view of wildlife. Animals are not frequently seen in the project area. Nevertheless, INO may ensure that the protocol of tunnel and

cavern making to be fine-tuned to minimise resultant ground vibration in such a way that it do not endanger any animals, micro habitats and the existing eco-system.

INO has proposed to carry out ground vibration monitoring study along with other rock mechanics and instrumentation studies during actual execution of the project as done in similar underground project commissioned elsewhere. This will be done continuously during blasting operations for all the major components of the project. Appropriate design and pattern for blasting and modern techniques based on the site geology, are proposed to be adopted such that the consequent vibration are restricted to the minimum possible. It is reported that all efforts will be taken to restrict the ground vibration in such a way that it does not endanger the wild animals, micro habitants and the existing eco-system. In addition, wherever the earth cover is less than 300 m; the blasting will be restricted to daytime and will not be carried out during night (dusk to dawn) and the periods when the animals are active, mostly dawn and dusk.

The noise and vibration associated with the transport of materials also has to be taken care, since this could have impact on the biota of the region. Similarly the sound and vibration from the equipments during the operational phase also has to be controlled. INO officials have already proposed control measures for problems related to noise and vibration. The sound and vibration from the machineries on the ground during their operation would be controlled by appropriate maintenance measures.

6.4 MANAGEMENT OF MUCK / DEBRIS

Disposal of the muck and other debris is a serious challenge in the case of INO construction. Large quantity of debris / muck that will be produced should be taken care of. Debris should be used to the maximum in construction such as lining the tunnel and laying the road. In house utilization of the muck and debris need to be strongly promoted to avoid various issues, including transportation and vehicular traffic density. INO also may disburse the debris to public for use as construction materials. The balance quantity of muck and debris should be properly stored so that it does not become an eyesore and do not pose threat to the downstream areas causing siltation and high suspended particulate matter in the air and water. The storage should

be with proper retention wall preventing the fine particulate matter from getting washed down during monsoon. In dry seaons, INO has plans to spray water over the muck / debris to control suspension / dispersal of dust. It is proper that silt traps are erected at appropriate locations so that the runoffs from the storage do not carry large quanity of silt.

About 10,000 m^2 is earmarked by the INO for storage yard, envisaging debris storage at any point of time not to exceed about 40,000 m^3. The debris / muck dumping and associated problems can be solved by taking adequate measures such as erecting wind screens around the dump yard and also using water sprayers. The INO officials have already identified such remedies. It is reported that 10 to 15% of the total muck and debris will be used for construction works related to INO while the rest would be disbursed for use in construction elsewhere. As there are no restrictions on transport of muck and debris in the area it is possible to evacuate the debris as soon as generated, minimizing storage at site and associated environmental hazards. INO is also planning to substitute river sand up to 80% with M-sand manufactured from the rock debris.

6.5 TRANSPORTATION

Laborers involved for the construction may be limited to the minimum in number. They should be sensitized to the ecological state of their area of work, nature conservation and be aware of the conservation strategies to avoid untoward effects. Movement of the workforce should be under strict control of the officials / group responsible for environmental protection. Travel and transport should be curtailed strictly to the work sites.

6.6 WORK FORCE RESIDENCES AND INFRASTRUCTURE FACILITIES

Strict measures should be taken to avoid use of wood, collected locally. The laborers should be provided with LPG instead of fuel wood. Proper facilities for their temporary residences should be given. They should be educated about nature conservation. It is likely to happen that the workforce involved in construction would settle in the area, and may decline to vacate even after completion of the work. Sufficient care should be taken to avoid such situation, by making appropriate clauses in the contracts with executing companies. The staff members involved in

construction and during the operation phase needs to be well aware of environmental and wildlife problems and related issues. They should be educated about conservation of environment. Cutting trees and other vegetation would lead to loss of feeding and breeding habitats to several species inhabiting the environs of the project and should be avoided.

6.7 WASTE DISPOSAL

Reducing, recycling and proper disposal of non-reusable waste generated will help reducing the impact on environment to a large extent. The workers and staff members involved in construction and operation needs to be sensified to ecological problems and related issues arising from unscientific waste disposal. Appropriate measures should be taken for disposal of sewage from the residences during construction as well as the operation phase. Similarly non decomposable wastes such as plastic, rubber, metal, lubricants and oils should be reused or managed appropriately.

6.8 DISASTER AND FIRE

Being equipped to handle disaster and fire is very important in the case of sophisticated and important project such as INO. The staff should be equipped/ trained to face any accidents such as fire or leakage of gases in the underground laboratory or elsewhere in their work area and / or surroundings. Sufficient provisions should be made to acquire fire fighting and communication equipments. Thrust also should be given to mentally equipping the staff to deal with untoward incidences by appropriate training and frequent refresher programmes. Hospital facility some where near Pottipuram is an essential requirement that INO can take initiative for.

6.9 FELLING OF TREES AND PLANTATION

As mentioned earlier, the proposed project is not expected to fell trees. In the portal entry area and the proposed sites for building construction do not have notable number of wild species of trees. Since, no forest land is required to be diverted for executing this project no compensatory afforestation programme is mandatory. However, as a commitment for nature conservation and environmental protection, the INO may arrange plantation programme, especially in their own

area and its surroundings. Some of the species that can be considered for planting are given in the table 21. The species suggested are commonly seen in and around the project area, fast growing and drought resistant. Seedlings / saplings of these species can be easily procured from local nurseries. A well managed green belt of these trees in the INO site skirting the buildings and the portal would improve the local environment by reducing the noise and dust pollution. A green belt is also advised outside the muck dump yard, which would improve the area astehtically as well may reduce the particulate matters from rising in the air.

Table 21: Some plant species suggested for planting in and around the INO site

Species		***Family***	***Vernacular name***
1	*Ailanthus excelsa*	Simaroubaceae	Peemaram
2	*Alangium salviifolium*	Alangiaceae	Azhinjil
3	*Albizia lebbeck*	Caesalpiniaceae	Vagai
4	*Azadirachta indica*	Meliaceae	Vembu; veppamaram
5	*Bambusa arundinacea*	Poaceae	Moongil
6	*Bauhinia racemosa*	Caesalpiniaceae	Aathi
7	*Bombax malabaricum*	Bombacaceae	Mul Ilavau
8	*Canthium dicoccum*	Rubiaceae	Nekkini
9	*Cassine glauca*	Celastraceae	Keeri maram
10	*Celtis philippensis*	Ulmaceae	Irumbili
11	*Chloroxylon swietenia*	Rutaceae	Porasu
12	*Commiphora caudata*	Burseraceae	Kiluvai
13	*Cordia monoica*	Boraginaceae	Siru Narivizhi
14	*Cordia wallichii*	Boraginaceae	Peru narivizhi
15	*Crateva adansonii*	Caryophyllaceae	Maavilangam
16	*Dalbergia latifolia*	Fabaceae	Eetti
17	*Dalbergia paniculata*	Fabaceae	Panivaagai
18	*Dalbergia sissoo*	Fabaceae	Thesimaram
19	*Debregaesia velutina*	Urticaceae	Kaattu Nochi
20	*Diospyros ebenum*	Ebenaceae	Karunthuvarai
21	*Diospyros montana*	Ebenaceae	Vakkanai
22	*Dolichandrone atrovirens*	Bignoniaceae	Pampaadhiri
23	*Dolichandrone spathacea*	Bignoniaceae	Irappaalai
24	*Erythrina stricta*	Fabaceae	Mulmurungai
25	*Ficus beddomei*	Moraceae	-
26	*Ficus benghalensis*	Moraceae	Aalamarm
27	*Ficus microcarpa*	Moraceae	Kallal
28	*Ficus racemosa*	Moraceae	Athi
29	*Ficus religiosa*	Moraceae	Arasamarm

30	*Ficus tomentosa*	Moraceae	Kalichi
31	*Gardenia latifolia*	Rubiaceae	Kambimaram
32	*Givotia moluccana*	Euphorbiaceae	Kottai thanakku
33	*Gmelina arborea*	Verbenaceae	Kumilamaram
34	*Grewia tiliifolia*	Tiliaceae	Thadachi
35	*Gyrocarpus americanus*	Hernandiaceae	Thanukku
36	*Holoptelea integrifolia*	Ulmaceae	Aaya
37	*Ixora arborea*	Rubiaceae	Korivi
38	*Lepisanthes tetraphylla*	Sapindaceae	Manippungan
39	*Maba buxifolia*	Ebenaceae	Chinnathuvarai
40	*Macaranga peltata*	Euphorbiaceae	Aanaaikkathu Ilai
41	*Mallotus philippensis*	Euphorbiaceae	Korangu-manjanatthi
42	*Mitragyna parvifolia*	Rubiaceae	Neerkkadambu
43	*Phyllanthus emblica*	Euphorbiaceae	Nelli
44	*Pongamia pinnata*	Fabaceae	Pungan
45	*Premna tomentosa*	Verbenaceae	Kosuthekku
46	*Santalam album*	Santalaceae	Santhanam
47	*Sapindus emarginatus*	Sapindaceae	Soppukaimarm
48	*Schefflera stellata*	Araliaceae	Paeimiratti
49	*Schleichera oleosa*	Sapindaceae	Poovan
50	*Stereospermum personatum*	Bignoniaceae	Paathiri
51	*Streblus asper*	Moraceae	Kuttipila
52	*Strychnos nux-vomica*	Loganiaceae	Yetti
53	*Strychnos potatorum*	Loganiaceae	Setthankottai
54	*Syzygium cuminii*	Myrtaceae	Naaval
55	*Tectona grandis*	Verbenaceae	Thekku
56	*Terminalia arjuna*	Combretaceae	Neermathi; Vellaimaruthu
57	*Terminalia bellirica*	Combretaceae	Thanikkai
58	*Terminalia chebula*	Combretaceae	Kadukkai
59	*Trema orientalis*	Urticaceae	Ambaraathi
60	*Tricalysia apiocarpa*	Rubiaceae	-
61	*Trichilia connaroides*	Meliaceae	Kaaraikaruvilangam
62	*Vitex altissima*	Verbenaceae	Mayiladi
63	*Ziziphus trinervia*	Rhamnaceae	Karukaavu

6.10 ENVIRONMENTAL MONITORING

The INO might develop a 'Local Environmental Monitoring Group' that monitor the construction phase closely to safeguard the environment in general and forest and wildlife in particular; especially as wild species are present in the area and they are reported to visit the

vicinity of the project site, although occasionally. Such a body can help rationalizing the INO's environmental management strategy. The monitoring Group mainly manned by in-house officials may also include experts in the field along with officials responsible for wildlife protection. This group can also be a means of liaising with the local public and dealing with their concerns.

An 'Environmental Monitoring Cell' which is manned by officials of the INO overseen by an 'Environmental Monitoring Panel' may be also constituted. The Environment Monitoring Panel may involve members from agencies such as the Tamil Nadu Forest Department, Pollution Control Board, and Academic / Research institutions. The broad mandate of this panel may be to oversee the environmental monitoring cell and Local Environmental Monitoring Group, and advise INO management on environment related matter as and when required.

The Environmental Monitoring (EM) Cell directly over see and ensure that the measures to be taken under the Environmental Management Plan is implemented strictly and to ensure the pollution parameters are within the prescribed limits. The cell in consultation with the local environmental group and environmental panel may also suggest appropriate changes in environmental management plan and its execution if found necessary in due course of time. The EM cell should be started in the initial stage of construction itself and its service should continue during the operation phase. Some of the responsibilities of the EM cell are the following.

- Conduct environmental awareness program to the workers, supervisory staff and laborers during the construction period.
- Organize Environmental Audits and report to TNPCB or any such authorities.
- Regularly monitor the environmental parameters and prepare reports as required by the TNPCB and other statutory authorities.
- Recommend necessary measures to improve the environmental conditions.
- Advise on any negligence or derelictions on the part of concerned staff or workers in observing EMP or Environmental code of conduct and to advice on the necessary steps to be adopted.

- Conduct safety programmes to create awareness among workers/staff.
- Train the staff and other workers on safety measures and conduct safety drills to educate them.

Infrastructure development for science and technology is vital for a country like India. In this direction, the proposed project, the single most expensive and comprehensive project towards cutting edge science and one of global importance would be a milestone. Nevertheless, during the construction phase, the project is likely to have certain impacts on the environment. However, these impacts are low considering the ecological setup of the area where the project is going to be located. By adopting proper planning and management measures these impacts could be reduced to a considerable extend. During the operation phase, the impact of the project on environment is negligible, except in situations such as certain untoward incident or disasters.

7 ACKNOWLEDGEMENT

The information provided in this report is based on the primary information generated during the rapid surveys. It also has drawn information from several published and unpublished reports, articles and other documents, which are listed under the reference section. We profusely thank the authors of those reports and those who shared other valuable information with us. In case any document, from which information were drawn but inadvertently missed out to quote, we express our apologies.

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Mixed dry deciduous forest

The Riparian forest

Moist deciduous forest

Dry deciduous forest

Savannah forest

Scrub forest

Habitat types of the study area

Proposed study site for INO

Proposed location of the portal

Ficus benghalensis

Strobilanthes cuspidatus

Diospyros chloroxylon

Ipomoea staphylina

Jatropha peltata

Aglaia elaeagnoidea

Some common plant species of the study site

The cart road leads to the study site

Pennisetum typhoides **cultivation is very common in and around the study area**

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10 APPENDICES

Appendix 1: ICAL detector – Brief description

Atmospheric neutrinos were first detected at the Kolar Gold Fields (KGF) underground laboratory in India in 1965 by the TIFR-Osaka-Durham collaboration and shortly thereafter by a team led by F. Reines in a gold mine in South Africa. In the late 1980s mining of gold at KGF became economically unviable and so the KGF underground laboratory was closed down as mining operations stopped. The India-based Neutrino Observatory (INO) is a newly proposed underground facility to revive the neutrino physics program in India. The proposed site is in the southern part of India in the state of Tamil Nadu and is about 100 km west of Madurai. It is proposed to construct an underground laboratory with a large cavern of dimensions 132m X 26m X 28m to house a 50 kton magnetized iron calorimeter (ICAL) tracking detector to study atmospheric neutrinos. In addition a couple of smaller caverns will also be constructed to host other smaller experiments. There will be at least 1.0 km rock overburden in all directions. The basic parameters of the INO facility and the ICAL detector are given in Table 1. The present document briefly describes the progress made in various activities, including a list of publications by the INO collaboration members.

The proposed ICAL detector will have a modular structure of total lateral size 48m X 16m and will consist of a stack of 150 horizontal layers of ~5.6 cm thick magnetized iron plates interleaved with 4 cm gaps to house the active detector layers. The ICAL detector will be subdivided into three modules of size 16m X 16m. The iron structure for this detector will be self supporting with the layer above resting on the layer immediately below using iron spacers located every 2m along the X direction. This will create 2m wide roads along the Y-direction for the insertion of active detector elements. The iron plates will be magnetized with a field strength of ~ 1.5 tesla to determine the charge of the muon produced by neutrino interaction inside the detector, so that the muon and antimuon induced events can be studied separately. The magnetic field will also help to measure the momentum of the final state particles, especially which of the muons produced in the neutrino interactions inside the ICAL detector.

The active detector elements are resistive plate chambers (RPCs), made up of a pair of 3mm thick glass plates of area 2m X 2m, separated by 2mm spacers. They are operated at a high voltage of about 9.9 KV in avalanche mode. A high energy charged particle, passing through RPC, leaves a signal with an efficiency of 90-95%. The read out of the RPCs will be performed by external orthogonal X & Y pickup strips of 3cm wide allowing determination of the x and y coordinates of the track of the charged particles through the RPC. The RPC location will provide the Z coordinate. The time resolution of ~1 nsec will enable one to distinguish upward going particles from downward going particles. Hence from the hit pattern observed in the RPCs, the energy and direction of the charged particles produced in the neutrino interaction can be reconstructed. Fig. 1 shows the overall layout of ICAL detector. Fig.2 shows a stack of 1m x 1m RPCs at TIFR being used to study the various parameters of the RPC operation.

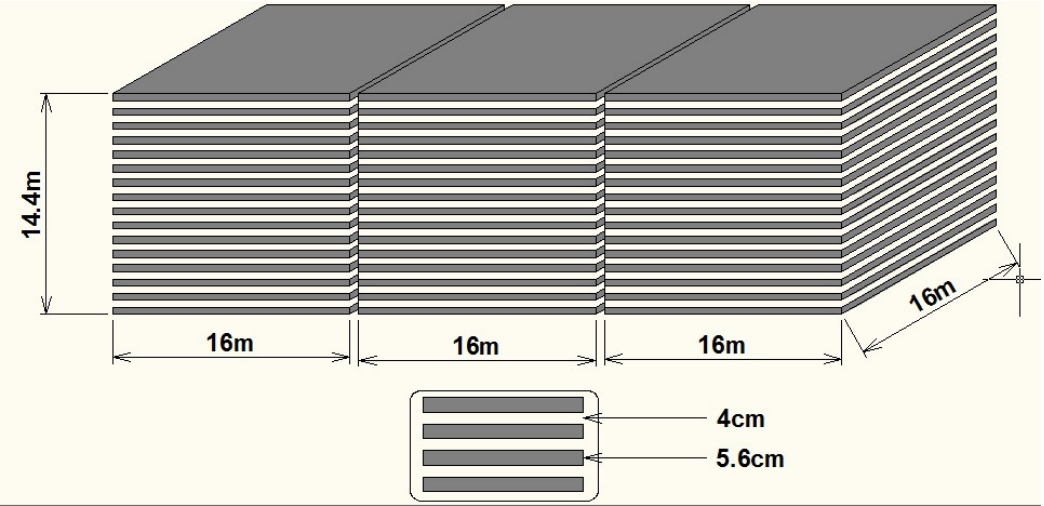

Fig. 1: Schematic view of the 50 kton iron calorimeter (ICAL).

Table 1 : Basic parameteres of the INO facility and the ICAL detector	
Underground Laboratory	
Length of tunnel	Approx. 2 km
Tunnel shape	D-shaped, 7.5m wide and 7.5 high
Rock overburden	1300m with a tunnel gradient of 1:15
Rock type and density	Charnockite, 2.9 gm/cc
Number of caverns	3 (one big, two small)
Size of the main cavern	132m X 26m X 32.6m (high)
Distance from CERN	7100 km
Distance from JPARC, Japan	6600 km
Iron Calorimeter	
Number of modules	3
Size of each module	16m X 16m X 14.4m (high)
Total size of the calorimeter	48m X 16m X 14.4m
Number of layers of iron plates	150
Size of each iron plate	4m X 2m X 56mm
Gap between plates in the stack	40mm
Weight of iron in each module	17000 tons (approx.)
Number of detector stacks	150
Size of each RPC detector	2m X 2m
Total number of RPCs required	28800
Number of electronics channels	3.6 million

The stack is now operating for about three years without much interruption. Some of the parameters that are tracked on a day-to-day basis are the RPC efficiencies for cosmic ray muons, absolute and relative timing resolutions as well as the stability of RPCs based on the monitoring data of the individual strip rates. Apart from studying various characteristics and long term stability of the RPCs under test, the stack is also being used to study and optimize a number of

parameters concerning the RPC gap, chamber design, gas mixture, readout electronics etc.

Gas Recirculation System

The gas volume (R-134a/isoC_4H_{10}/SF_6 in the 95/4.5/0.5 mass ratio) of the ICAL detector is going to be more than 200m^3. The *conventional* free-flow gas systems are not suitable for ICAL, mainly due to high recurring cost of the input gases and potential environmental hazard and safety. Therefore, appropriate techniques are currently being developed to recycle the exhaust gas mixture from the RPCs. In the open-loop recycling system, the used gas mixture is first purified and individual gases are extracted using fractional condensation method. In the closed-loop system, the gas mixture is purified and topped up with fresh gases as required before reusing the same. Prototype units based on both these designs have been developed and their performances are being studied using a Residual Gas Analyser (RGA) system that is setup in house.

In order to determine optimized flow rate of gas mixture through an RPC, a chamber has been sealed with its gas mixture and its long-term performance studied in terms of its chamber current, counting rate, efficiency and other operating characteristics, using cosmic ray muons. The sealed gas is analyzed using RGA at the end of these studies to look for possible gas radical production. These studies, which are in progress, have already yielded very important results.

Neutrino-less Double Beta Decay experiment at INO

In addition to the main detector ICAL, there is also a proposal to build a cryogenic bolometer detector for studying Neutrino-less double beta decay (NDBD) in 124Sn to be located in a smaller cavern at INO. The laboratory will be located at full depth.

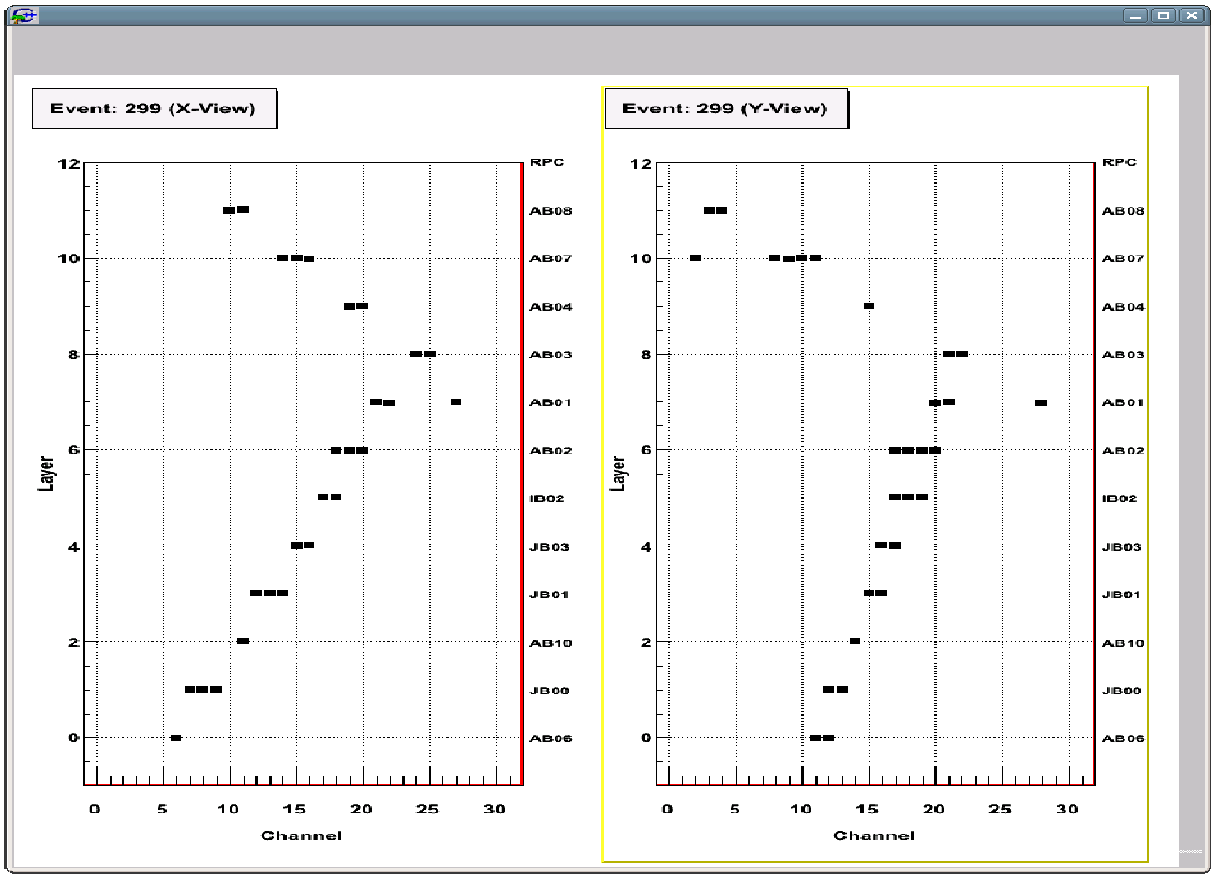

Fig. 2: RPC stack and an interesting cosmic ray muon event tracked by the stack

For NDBD experiment, low radiation background levels are of paramount importance and hence heavy shielding is required in and around the cryostat, which houses the detector. Another important factor is the vibration isolations, as these will interfere with measurements. The setup also should have suitable faraday cage arrangement for EMI shielding. It is envisaged that a ~3m tall, ~1.5m dia cryostat, which will be surrounded by radiation shields of lead and paraffin (overall dia ~ 3m). A clear access equivalent of cryostat height (i.e. 3m) is required below the cryostat for mounting/dismounting shields to access the detectors inside the cryostat. In addition, enough headroom is necessary for assembling and maintenance of the cryostat. Since the overall tunnel height is ~5m, we would like to have a 10m x 4m wide pit with a depth of ~6m, providing a total height of 10m in the cryostat vicinity. A schematic layout is shown in Fig. 3.

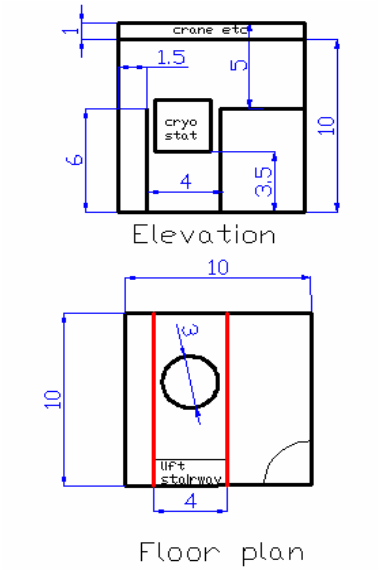

Fig 3: A Schematic of the proposed lab NDBD (all dimensions are in meters)

Suitable stair way and lift access should be provided in the pit. The cryostat would be partly inside the pit and partly above floor level. Further, the laboratory would need to accommodate the associated vacuum systems, Helium re-circulation systems, signal processing electronics, data acquisition system etc. The laboratory will have a floor space of 10m x 10m.

The NDBD experiment will require liquid Nitrogen with a consumption rate ~100 liters per day. The liquid nitrogen will be stored in a 2000 liter capacity tank outside and will be transported to the cavern (control room/lab) in standard laboratory dewars of 200 liter capacity.

The NDBD experiment does not use any hazardous materials. In the main experiment (NDBD), the Helium Gas is in the closed-circuit (hermetically sealed) and is expected to be around ~200

gas litres. The gas is never vented, unless the units fail. The liquid Nitrogen consumption is expected to be ~100 liquid liters per day (~8 cubic meters of gas volume). The liquid Nitrogen will be stored in portable laboratory-use containers having approx 200 liquid litres capacity, and will have to be moved in/out from a main liquid storage kept in the portal. The boiled-off Nitrogen will be vented into the room, as is usual practice in all labs, the volume will be negligibly small to affect the Oxygen concentration in the Cavern. A 2000 liter liquid nitrogen container will be stored at portal to be filled periodically. No other gases are used in the NDBD experiment. In addition, the lab will have lead and sealed paraffin for shielding material.

Appendix 2: Trees recorded in the study area

No	***Species***	***Family***
1	*Acacia chundra*	Mimosaceae
2	*Acacia farnesiana*	Mimosaceae
3	*Acacia leucophloea*	Mimosaceae
4	*Acacia mellifera*	Mimosaceae
5	*Acacia nilotica*	Mimosaceae
6	*Acacia pennata*	Mimosaceae
7	*Acacia polyacantha*	Mimosaceae
8	*Agalaia elaeagnoidea*	Meliaceae
9	*Ailanthus excelsa*	Simaroubaceae
10	*Alangium salviifolium*	Alangiaceae
11	*Albizia amara*	Caesalpiniaceae
12	*Albizia lebbeck*	Caesalpiniaceae
13	*Annona squamosa*	Annonaceae
14	*Anogeissus latifolia*	Combretaceae
15	*Atalantia monophylla*	Rutaceae
16	*Atalantia racemosa*	Rutaceae
17	*Azadirachta indica*	Meliaceae
18	*Bambusa arundinacea*	Poaceae
19	*Bauhinia racemosa*	Caesalpiniaceae
20	*Bombax malabaricum*	Bombacaceae
21	*Buchanania lanzan*	Anacardiaceae
22	*Canthium dicoccum*	Rubiaceae
23	*Capparis grandis*	Capparidaceae
24	*Cassine glauca*	Celastraceae
25	*Celtis philippensis*	Ulmaceae
26	*Chloroxylon swietenia*	Rutaceae
27	*Clerodendrum viscosum*	Verbenaceae
28	*Commiphora berryi*	Burseraceae
29	*Commiphora caudata*	Burseraceae
30	*Cordia monoica*	Boraginaceae
31	*Cordia rothii*	Boraginaceae

32	*Cordia wallichii*	Boraginaceae
33	*Crateva adansonii*	Caryophyllaceae
34	*Crateva magna*	Caryophyllaceae
35	*Dalbergia latifolia*	Fabaceae
36	*Dalbergia paniculata*	Fabaceae
37	*Dalbergia sissoo*	Fabaceae
38	*Debregaesia velutina*	Urticaceae
39	*Delonix regia*	Mimosaceae
40	*Dichrostachys cinerea*	Mimosaceae
41	*Diospyros chloroxylon*	Ebenaceae
42	*Diospyros montana*	Ebenaceae
43	*Dolichandrone atrovirens*	Bignoniaceae
44	*Dolichandrone spathacea*	Bignoniaceae
45	*Ehretia ovalifolia*	Boraginaceae
46	*Ehretia pubescens*	Boraginaceae
47	*Erythrina stricta*	Fabaceae
48	*Euphorbia antiquorum*	Euphorbiaceae
49	*Euphorbia trigonum*	Euphorbiaceae
50	*Ficus beddomei*	Moraceae
51	*Ficus benghalensis*	Moraceae
52	*Ficus hispida*	Moraceae
53	*Ficus microcarpa*	Moraceae
54	*Ficus racemosa*	Moraceae
55	*Ficus religiosa*	Moraceae
56	*Ficus tinctoria* ssp. *parasitica*	Moraceae
57	*Ficus tomentosa*	Moraceae
58	*Ficus tsjakela*	Moraceae
59	*Flacourtia indica*	Flacourtiaceae
60	*Gardenia gummifera*	Rubiaceae
61	*Gardenia latifolia*	Rubiaceae
62	*Gardenia resinifera*	Rubiaceae
63	*Givotia moluccana*	Euphorbiaceae
64	*Gmelina arborea*	Verbenaceae
65	*Gyrocarpus americanus*	Hernandiaceae
66	*Holoptelea integrifolia*	Ulmaceae
67	*Ixora arborea*	Rubiaceae
68	*Lepisanthes tetraphylla*	Sapindaceae
69	*Maba buxifolia*	Ebenaceae
70	*Macaranga peltata*	Euphorbiaceae
71	*Mallotus philippensis*	Euphorbiaceae
72	*Mitragyna parvifolia*	Rubiaceae
73	*Moringa concanensis*	Moringaceae
74	*Naringi crenulata*	Rutaceae
75	*Phyllanthus emblica*	Euphorbiaceae

76	*Pongamia pinnata*	Fabaceae
77	*Premna corymbosa*	Verbenaceae
78	*Premna tomentosa*	Verbenaceae
79	*Prosopis juliflora*	Mimosaceae
80	*Santalam album*	Santalaceae
81	*Sapindus emarginatus*	Sapindaceae
82	*Schefflera stellata*	Araliaceae
83	*Schleichera oleosa*	Sapindaceae
84	*Stereospermum personatum*	Bignoniaceae
85	*Streblus asper*	Moraceae
86	*Strychnos nux-vomica*	Loganiaceae
87	*Strychnos potatorum*	Loganiaceae
88	*Tectona grandis*	Verbenaceae
89	*Terminalia arjuna*	Combretaceae
90	*Terminalia bellirica*	Combretaceae
91	*Terminalia chebula*	Combretaceae
92	*Thevetia peruviana*	Apocynaceae
93	*Trema orientalis*	Urticaceae
94	*Tricalysia apiocarpa*	Rubiaceae
95	*Trichilia connaroides*	Meliaceae
96	*Vepris bilocularis*	Rutaceae
97	*Vitex altissima*	Verbenaceae
98	*Wrightia tinctoria*	Apocynaceae
99	*Ziziphus mauritiana*	Rhamnaceae
100	*Ziziphus rugosa*	Rhamnaceae
101	*Ziziphus trinervia*	Rhamnaceae

Appendix 3: Shrub species recorded in the study area		
No	***Species***	***Family***
1	*Abutilon hirtum*	Malvaceae
2	*Abutilon indicum*	Malvaceae
3	*Acalypha fruiticosa*	Euphorbiaceae
4	*Ageratina adenophora*	Asteraceae
5	*Alstonia venenata*	Apocynaceae
6	*Anisomeles malabarica*	Lamiaceae
7	*Azima tetracantha*	Salvadoraceae
8	*Barleria acuminata*	Acanthaceae
9	*Barleria prionitis*	Acanthaceae
10	*Barleria tomentosa*	Acanthaceae
11	*Benkara malabarica*	Rubiaceae
12	*Breynia vitis-idaea*	Euphorbiaceae
13	*Cadaba trifoliata*	Caryophyllaceae

14	*Capparis divaricata*	Capparidaceae
15	*Carissa carandas*	Apocynaceae
16	*Carissa spinarum*	Apocynaceae
17	*Carmona retusa*	Boraginaceae
18	*Cassia auriculata*	Caesalpiniaceae
19	*Chromolaena odorata*	Asteraceae
20	*Cipadessa baccifera*	Meliaceae
21	*Clausena dentata*	Rutaceae
22	*Clerodendrum phlomoides*	Verbenaceae
23	*Crotalaria longipes*	Fabaceae
24	*Dodonaea viscosa*	Sapindaceae
25	*Erythroxylum monogynum*	Erythroxylaceae
26	*Fluggea leucopyrus*	Euphorbiaceae
27	*Fluggea virosa*	Euphorbiaceae
28	*Gmelina asiatica*	Verbenaceae
29	*Helicteres isora*	Sterculiaceae
30	*Hibiscus lunarifolius*	Malvaceae
31	*Hibiscus surattensis*	Malvaceae
32	*Hibiscus vitifolia*	Malvaceae
33	*Indigofera longiracemosa*	Fabaceae
34	*Jatropha curcus*	Euphorbiaceae
35	*Jatropha gossypifolia*	Euphorbiaceae
36	*Jatropha peltata*	Euphorbiaceae
37	*Justicia betonica*	Acanthaceae
38	*Kleinia grandiflora*	Asteraceae
39	*Lantana camara*	Verbenaceae
40	*Maytenus ovata*	Celastraceae
41	*Mundulia sericea*	Fabaceae
42	*Murraya paniculata*	Rutaceae
43	*Opuntia stricta*	Cactaceae
44	*Osbeckia aspera*	Melastomataceae
45	*Pavetta indica*	Rubiaceae
46	*Pavetta montana*	Rubiaceae
47	*Phoenix lourierii*	Arecaceae
48	*Phyllanthus polyphyllus*	Euphorbiaceae
49	*Phyllanthus reticulatus*	Fabaceae
50	*Psychotria* sp.	Rubiaceae
51	*Randia brandisii*	Rubiaceae
52	*Randia dumetorum*	Rubiaceae
53	*Rhus mysorensis*	Rhamnaceae
54	*Solanum pubescens*	Solanaceae
55	*Solanum surrettense*	Solanaceae
56	*Solanum torvum*	Solanaceae
57	*Solanum violaceum*	Solanaceae

58	*Strobilanthes consanguinea*	Acanthaceae
59	*Strobilanthes cuspidatus*	Acanthaceae
60	*Suregada angustifolia*	Euphorbiaceae
61	*Tarenna asiatica*	Rubiaceae
62	*Taxillus cuneatus*	Loranthaceae
63	*Taxillus heyneanus*	Loranthaceae
64	*Taxillus recurva*	Loranthaceae
65	*Triumfetta pentandra*	Tiliaceae
66	*Triumfetta pilosa*	Tiliaceae
67	*Triumfetta rotundifolia*	Tiliaceae
68	*Waltheria indica*	Sterculiaceae
69	*Xanthium indicum*	Asteraceae

Appendix 4: Herbaceous species recorded in the study area		
No	***Species***	***Family***
1	*Abutilon persicum*	Malvaceae
2	*Acalypha indica*	Euphorbiaceae
3	*Acalypha paniculata*	Euphorbiaceae
4	*Acanthospermum hispidum*	Asteraceae
5	*Achyranthes aspera*	Amaranthaceae
6	*Achyranthes bidentata*	Amaranthaceae
7	*Aerva lanata*	Amaranthaceae
8	*Aerva persica*	Amaranthaceae
9	*Ageratum conyzoides*	Asteraceae
10	*Aloe vera*	Agavaceae
11	*Alternanthera pungens*	Amaranthaceae
12	*Alternanthera tenella*	Amaranthaceae
13	*Alysicarpus monilifer*	Fabaceae
14	*Alysicarpus rugosus*	Fabaceae
15	*Amaranthus spinosus*	Amaranthaceae
16	*Amaranthus viridis*	Amaranthaceae
17	*Andrographis alata*	Acanthaceae
18	*Aneilema paniculata*	Commelinaceae
19	*Anisochilus carnosus*	Lamiaceae
20	*Anisochilus scaber*	Lamiaceae
21	*Anisomeles indica*	Lamiaceae
22	*Asclepias curassavica*	Asclepiadaceae
23	*Asystasia dalzelliana*	Acanthaceae
24	*Asystasia gangetica*	Acanthaceae
25	*Bidens pilosa*	Asteraceae
26	*Biophytum sensitivum*	Oxalidaceae
27	*Blainvillea acmella*	Asteraceae

28	*Blepharis maderaspatensis*	Acanthaceae
29	*Blepharis molluginifolia*	Acanthaceae
30	*Blumea lacera*	Asteraceae
31	*Blumea mollis*	Asteraceae
32	*Boerhavia diffusa*	Nyctaginaceae
33	*Boerhavia erecta*	Nyctaginaceae
34	*Borreria hispida*	Rubiaceae
35	*Borreria ocymoides*	Rubiaceae
36	*Borreria pusilla*	Rubiaceae
37	*Bulbostylis barbata*	Cyperaceae
38	*Bulbostylis puberula*	Cyperaceae
39	*Canscora decussata*	Gentianaceae
40	*Caralluma attenualta*	Asclepiadaceae
41	*Caralluma umbellata*	Asclepiadaceae
42	*Cassia hirsuta*	Caesalpiniaceae
43	*Cassia italica*	Caesalpiniaceae
44	*Cassia mimosoides*	Caesalpiniaceae
45	*Cassia obtusa*	Caesalpiniaceae
46	*Cassia occidentalis*	Caesalpiniaceae
47	*Cassia tora*	Caesalpiniaceae
48	*Celosia polygonoides*	Amaranthaceae
49	*Centella asiatica*	Apiaceae
50	*Cleome felina*	Caryophyllaceae
51	*Cleome viscosa*	Caryophyllaceae
52	*Cochorus aestuans*	Tiliaceae
53	*Commelina benghalensis*	Commelinaceae
54	*Commelina clavata*	Commelinaceae
55	*Commelina longifolia*	Commelinaceae
56	*Conyza bonariensis*	Asteraceae
57	*Conyza leucantha*	Asteraceae
58	*Conyza stricta*	Asteraceae
59	*Corchorus tridens*	Tiliaceae
60	*Crassocephalum crepedioides*	Asteraceae
61	*Crossandra infundibuliformis*	Acanthaceae
62	*Crotalaria biflora*	Fabaceae
63	*Crotalaria hirta*	Fabaceae
64	*Crotalaria mysorensis*	Fabaceae
65	*Crotalaria retusa*	Fabaceae
66	*Crotalaria* sp.	Fabaceae
67	*Crotalaria verrucosa*	Fabaceae
68	*Croton banblandianus*	Euphorbiaceae
69	*Cynotis tuberosa*	Commelinaceae
70	*Cynotis villosa*	Commelinaceae
71	*Cyperus articulatus*	Cyperaceae

72	*Cyperus corymbosus*	Cyperaceae
73	*Cyperus difformis*	Cyperaceae
74	*Cyperus exaltatus*	Cyperaceae
75	*Cyperus globosus*	Cyperaceae
76	*Cyperus iria*	Cyperaceae
77	*Cyperus pangorai*	Cyperaceae
78	*Cyperus rotundus*	Cyperaceae
79	*Cyperus triceps*	Cyperaceae
80	*Desmodium triflorum*	Fabaceae
81	*Dicliptera cuneata*	Acanthaceae
82	*Didymocarpus tomentosus*	Gesneriaceae
83	*Digera muricata*	Amaranthaceae
84	*Emelia sonchifolia*	Asteraceae
85	*Emelia zeylanica*	Asteraceae
86	*Eriocaulon thwaitsii*	Eriocaulaceae
87	*Eriocaulon truncatun*	Eriocaulaceae
88	*Euphorbia hirta*	Euphorbiaceae
89	*Euphorbia rothiana*	Euphorbiaceae
90	*Euphorbia thymifolia*	Euphorbiaceae
91	*Evolvulus alsinoides*	Convolvulaceae
92	*Exacum sessile*	Gentianaceae
93	*Fimbristylis complanata*	Cyperaceae
94	*Fimbristylis falcata*	Cyperaceae
95	*Fimbristylis ovata*	Cyperaceae
96	*Gisekia pharnaceoides*	Aizoaceae
97	*Gloriosa suberba*	Liliaceae
98	*Gomphrena decumbens*	Amaranthaceae
99	*Gynandropsis pentaphylla*	Caryophyllaceae
100	*Hibiscus micranthus*	Malvaceae
101	*Hybanthus enneaspermus*	Caryophyllaceae
102	*Hyptis suaveolens*	Lamiaceae
103	*Indigofera barberii*	Fabaceae
104	*Indigofera cassioides*	Fabaceae
105	*Indigofera linnaei*	Fabaceae
106	*Indigofera trita*	Fabaceae
107	*Indigofera viscosa*	Fabaceae
108	*Indoneesiella echioides*	Acanthaceae
109	*Justicia simplex*	Acanthaceae
110	*Justicia tranquebariensis*	Acanthaceae
111	*Kalanchoe laciniata*	Crassulaceae
112	*Lagascea mollis*	Asteraceae
113	*Lantana wightiana*	Verbenaceae
114	*Leanotis nepetifolia*	Lamiaceae
115	*Leucas aspera*	Lamiaceae

116	*Leucas biflora*	Lamiaceae
117	*Leucas cephalotus*	Lamiaceae
118	*Leucas martinicensis*	Lamiaceae
119	*Leucas vestita*	Lamiaceae
120	*Lindernia antipoda*	Scrophulariaceae
121	*Ludwigia octavalis*	Onagraceae
122	*Ludwigia perennis*	Onagraceae
123	*Mariscus squarrosus*	Cyperaceae
124	*Martynia annua*	Pedaliaceae
125	*Merremia tridentata*	Convolvulaceae
126	*Micrargeria wightii*	Scrophulariaceae
127	*Mollugo cerviana*	Aizoaceae
128	*Mollugo nudicaulis*	Aizoaceae
129	*Mollugo pentaphylla*	Aizoaceae
130	*Monothecium aristatum*	Acanthaceae
131	*Nothosaerva brachiata*	Amaranthaceae
132	*Ocimum canum*	Lamiaceae
133	*Ocimum sanctum*	Lamiaceae
134	*Oldenlandia aspera*	Rubiaceae
135	*Oldenlandia biflora*	Rubiaceae
136	*Oldenlandia corymbosa*	Rubiaceae
137	*Oldenlandia umbellata*	Rubiaceae
138	*Orthosiphon diffuses*	Lamiaceae
139	*Orthosiphon pallidus*	Lamiaceae
140	*Osbeckia octandra*	Melastomataceae
141	*Oxalis corniculata*	Oxalidaceae
142	*Parthenium hysterophorus*	Asteraceae
143	*Pavonia procumbens*	Malvaceae
144	*Pavonia zeylanica*	Malvaceae
145	*Peristrophe bicalyculata*	Acanthaceae
146	*Phyla nodiflora*	Verbenaceae
147	*Phyllanthus amarus*	Euphorbiaceae
148	*Phyllanthus maderaspatensis*	Euphorbiaceae
149	*Phyllanthus wightianus*	Euphorbiaceae
150	*Plumbago zeylanica*	Plumbaginaceae
151	*Polycarpaea corymbosa*	Caryophyllaceae
152	*Polygala bulbothrix*	Polygalaceae
153	*Polygonum hydropiper*	Polygonaceae
154	*Portulaca oleracea*	Portulacaceae
155	*Portulaca quadrifida*	Portulacaceae
156	*Portulaca tuberosa*	Portulacaceae
157	*Pouzolzia bennettiana*	Urticaceae
158	*Pouzolzia indica*	Urticaceae
159	*Priva cordifolia*	Verbenaceae

160	*Pseudarthria viscida*	Fabaceae
161	*Psilotrichum elliottii*	Amaranthaceae
162	*Pupalia lappacea*	Amaranthaceae
163	*Pycreus pumilus*	Cyperaceae
164	*Pycreus puncticulatus*	Cyperaceae
165	*Rhynacanthus naustatus*	Acanthaceae
166	*Rhynchoglossum zeylanicum*	Gesneriaceae
167	*Ruellia patula*	Acanthaceae
168	*Sansevieria roxburghiana*	Agavaceae
169	*Scoparia dulcis*	Scrophulariaceae
170	*Sebastiania chamaelea*	Euphorbiaceae
171	*Sida acuta*	Malvaceae
172	*Sida cordata*	Malvaceae
173	*Sida cordifolia*	Malvaceae
174	*Sigesbeckia orientalis*	Asteraceae
175	*Solanum nigrum*	Solanaceae
176	*Sonchus oleraceous*	Asteraceae
177	*Sophubia trifida*	Scrophulariaceae
178	*Spilanthes acmella*	Asteraceae
179	*Stachytarpheta jamaicensis*	Verbenaceae
180	*Striga asiatica*	Scrophulariaceae
181	*Synedrella nodiflora*	Asteraceae
182	*Tephrosia purpurea*	Fabaceae
183	*Tephrosia villosa*	Fabaceae
184	*Trianthema decandra*	Aizoaceae
185	*Trianthema portulacastrum*	Aizoaceae
186	*Tribulus subramaniamii*	Zygophyllaceae
187	*Tribulus terrestris*	Zygophyllaceae
188	*Trichodesma indicum*	Boraginaceae
189	*Trichodesma zeylanicum*	Boraginaceae
190	*Trichurus monsoniae*	Amaranthaceae
191	*Tridax procumbens*	Asteraceae
192	*Utricularia aurea*	Lentibulariaceae
193	*Utricularia scandens*	Lentibulariaceae
194	*Vernonia albicans*	Asteraceae
195	*Vernonia cinerea*	Asteraceae
196	*Vicoa indica*	Asteraceae
197	*Wedelia urticifolia*	Asteraceae
198	*Zornia gibbosa*	Fabaceae

Appendix 5: Climbers/stragglers recorded in the study area			
No	***Species***	***Family***	***Habit***
1	*Abrus precatorius*	Fabaceae	Straggler
2	*Acacia caesia*	Mimosaceae	Straggler
3	*Acacia planifrons*	Mimosaceae	Straggler
4	*Acacia torta*	Mimosaceae	Straggler
5	*Argyria cuneata*	Convolvulaceae	Straggler
6	*Argyria hirsuta*	Convolvulaceae	Straggler
7	*Argyria pomacea*	Convolvulaceae	Straggler
8	*Aristolochia indica*	Euphorbiaceae	Straggler
9	*Aristolochia tagala*	Euphorbiaceae	Straggler
10	*Asparagus racemosus*	Asparagaceae	Straggler
11	*Butea parviflora*	Fabaceae	Straggler
12	*Cadaba indica*	Caryophyllaceae	Straggler
13	*Canavalia virosa*	Fabaceae	Straggler
14	*Cansjeera rheedii*	Opeliaceae	Straggler
15	*Capparia aphylla*	Capparidaceae	Straggler
16	*Capparis roxburghiana*	Capparidaceae	Straggler
17	*Capparis sepiaria*	Capparidaceae	Straggler
18	*Capparis spinosa*	Capparidaceae	Straggler
19	*Capparis zeylanica*	Capparidaceae	Straggler
20	*Cardiospermum canescens*	Sapindaceae	Climber
21	*Cardiospermum halicacabum*	Sapindaceae	Climber
22	*Cayratia pedata*	Vitaceae	Climber
23	*Cayratia trifoliata*	Vitaceae	Climber
24	*Celastrus paniculatus*	Celastraceae	Straggler
25	*Centrosema pubescens*	Fabaceae	Climber
26	*Cissampelos pariera*	Menispermaceae	Straggler
27	*Cissus bicolor*	Vitaceae	Climber
28	*Cissus quadrangularis*	Vitaceae	Climber
29	*Cissus repanda*	Vitaceae	Climber
30	*Cissus vitigenea*	Vitaceae	Climber
31	*Clematis gouriana*	Ranunculaceae	Straggler
32	*Coccinia indica*	Cucurbitaceae	Climber
33	*Cocculus hirsutus*	Menispermaceae	Straggler
34	*Cocculus pendulus*	Menispermaceae	Straggler
35	*Cryptolepis buchananii*	Asclepiadaceae	Climber
36	*Decalepis hamiltonii*	Asclepiadaceae	Climber
37	*Diplocyclos palmatus*	Cucurbitaceae	Climber
38	*Dunbaria heyneana*	Fabaceae	Straggler
39	*Glycine javanica*	Fabaceae	Straggler
40	*Grewia disperma*	Tiliaceae	Straggler
41	*Grewia flavescens*	Tiliaceae	Straggler
42	*Grewia hirsuta*	Tiliaceae	Straggler

43	*Grewia tenax*	Tiliaceae	Straggler
44	*Grewia* sp.	Tiliaceae	Straggler
45	*Grewia villosa*	Tiliaceae	Straggler
46	*Hemidesmus indicus*	Asclepiadaceae	Climber
47	*Hugonia mystax*	Linaceae	Straggler
48	*Hyptage benghalensis*	Malphigiaceae	Straggler
49	*Ichnocarpus frutescens*	Asclepiadaceae	Climber
50	*Ipomoea pescarpae*	Convolvulaceae	Climber
51	*Ipomoea pesti-gridis*	Convolvulaceae	Climber
52	*Ipomoea staphylina*	Convolvulaceae	Climber
53	*Jasminum auriculatum*	Oleaceae	Straggler
54	*Jasminum azoricum*	Oleaceae	Straggler
55	*Jasminum rigidum*	Oleaceae	Straggler
56	*Loseneriella obtusifolia*	Hippocrateaceae	Straggler
57	*Maclura spinosa*	Moraceae	Straggler
58	*Mikania cordata*	Asteraceae	Climber
59	*Mucuna atropurpurea*	Fabaceae	Straggler
60	*Mucuna monosperma*	Fabaceae	Straggler
61	*Mucuna pruriens*	Fabaceae	Straggler
62	*Mukia maderaspatana*	Cucurbitaceae	Climber
63	*Pachygone ovata*	Menispermaceae	Straggler
64	*Parsonsia alboflavescens*	Asclepiadaceae	Climber
65	*Passiflora foetida*	Passifloraceae	Climber
66	*Pergularia daemia*	Asclepiadaceae	Climber
67	*Polygonum chinensis*	Polygonaceae	Straggler
68	*Polygonum nepalensis*	Polygonaceae	Straggler
69	*Pterolobium hexapetalum*	Fabaceae	Straggler
70	*Rhynchosia capitata*	Fabaceae	Straggler
71	*Rhynchosia minima*	Fabaceae	Straggler
72	*Rivea hypocrateriformis*	Convolvulaceae	Straggler
73	*Salacia reticulata*	Hippocrateaceae	Straggler
74	*Sarcostemma brunoniana*	Asclepiadaceae	Climber
75	*Sarcostemma intermedia*	Asclepiadaceae	Climber
76	*Scutia myrtina*	Rhamnaceae	Straggler
77	*Secamone emetica*	Asclepiadaceae	Climber
78	*Solena amplexicaulis*	Cucurbitaceae	Climber
79	*Tetrastigma lanceolaria*	Vitaceae	Climber
80	*Tetrastigma nilagirense*	Vitaceae	Climber
81	*Tinospora cordifolia*	Menispermaceae	Straggler
82	*Toddalia asiatica*	Rutaceae	Straggler
83	*Tylophora indica*	Asclepiadaceae	Climber
84	*Watakaka volubilis*	Asclepiadaceae	Climber
85	*Zehnaria mysorensis*	Cucurbitaceae	Climber
86	*Ziziphus oenoplia*	Rhamnaceae	Straggler

Appendix 6: Grasses recorded in the study area		
No	***Species***	***Family***
1	*Acrachne racemosa*	Poaceae
2	*Alloteropsis cimcinna*	Poaceae
3	*Apluda mutica*	Poaceae
4	*Aristida adscensionis*	Poaceae
5	*Aristida funiculata*	Poaceae
6	*Aristida hystrix*	Poaceae
7	*Arthraxon micans*	Poaceae
8	*Arundinella ciliata*	Poaceae
9	*Arundinella setosa*	Poaceae
10	*Arundinella tuberculata*	Poaceae
11	*Bothriochloa pertusa*	Poaceae
12	*Brachiaria ramosa*	Poaceae
13	*Brachiaria remota*	Poaceae
14	*Cenchrus biflorus*	Poaceae
15	*Cenchrus ciliaris*	Poaceae
16	*Chloris barbata*	Poaceae
17	*Chloris dolichostachya*	Poaceae
18	*Chloris roxburghiana*	Poaceae
19	*Chrysopogon aciculatus*	Poaceae
20	*Chrysopogon asper*	Poaceae
21	*Chrysopogon hackelii*	Poaceae
22	*Cymbopogon citratus*	Poaceae
23	*Cynodon barberii*	Poaceae
24	*Cynodon dactylon*	Poaceae
25	*Cyrtococcum trigonum*	Poaceae
26	*Dactyloctenium aegyptium*	Poaceae
27	*Digitaria bicornis*	Poaceae
28	*Digitaria longifolia*	Poaceae
29	*Eleusine indica*	Poaceae
30	*Enneapogon schimperianus*	Poaceae
31	*Enteropogon monostachyas*	Poaceae
32	*Eragrostiella bifaria*	Poaceae
33	*Eragrostis amabilis*	Poaceae
34	*Eragrostis atrovirens*	Poaceae
35	*Eragrostis maderaspatana*	Poaceae
36	*Eragrostis plumosa*	Poaceae
37	*Eragrostis unioloides*	Poaceae
38	*Garnotia courtallensis*	Poaceae
39	*Garnotia elata*	Poaceae

40	*Garnotia tenella*	Poaceae
41	*Heteropogon contortus*	Poaceae
42	*Isachnae kunthiana*	Poaceae
43	*Oplismenus compositus*	Poaceae
44	*Oropetium thomaeum*	Poaceae
45	*Panicum notatum*	Poaceae
46	*Panicum psilopodium*	Poaceae
47	*Panicum trypheron*	Poaceae
48	*Perotis indica*	Poaceae
49	*Phragmites karka*	Poaceae
50	*Poganatherum critinum*	Poaceae
51	*Rhynchelytrum repens*	Poaceae
52	*Sacciolepis indica*	Poaceae
53	*Setaria pumila*	Poaceae
54	*Sporobolous coromandelicus*	Poaceae
55	*Sporobolous indicus*	Poaceae
56	*Sporobolous spicatus*	Poaceae
57	*Sporobolous wallichii*	Poaceae
58	*Themeda cymbaria*	Poaceae
59	*Themeda triandra*	Poaceae
60	*Trachys muricata*	Poaceae
61	*Tragus roxburghii*	Poaceae
62	*Tripogon bromoides*	Poaceae
63	*Zenkaria elegans*	Poaceae

Appendix 7: Birds recorded in the study area			
No	***Common Name***	***Scientific name***	***Status****
1	Alexandrine Parakeet	*Psittacula eupatria*	LC
2	Ashy drongo	*Dicrurus leucophaeus*	LC
3	Ashy prinia	*Prinia socialis*	LC
4	Ashy Woodswallow	*Artamus fuscus*	LC
5	Asian fairy blue bird	*Irena puella*	LC
6	Asian koel	*Eudynamys scolopacea*	LC
7	Asian palm swift	*Cypsiurus balasiensis*	LC
8	Asian paradise-flycather	*Terpsiphone paradise*	LC
9	Barn Owl*	*Tyto alba*	LC
10	Barn Swallow	*Hirundo rustica*	LC
11	Barred buttonquail	*Turnix suscitator*	LC
12	Baya Weaver bird*	*Ploceus philippinus*	LC
13	Baybacked Shirike*	*Lanius vittatus*	LC
14	Black Bird*	*Turdus merula*	LC
15	Black drongo	*Dicrurus macrocercus*	LC

16	Black eagle	*Ictinaetus malayensis*	LC
17	Black or King Vulture*	*Sarcogyps calvus*	CE
18	Black shouldered kite	*Elanus caeruleus*	LC
19	Blackcapped Kingfisher*	*Halcyon pileata*	LC
20	Black-headed Munia	*Lonchura malacca*	LC
21	Black-hooded oriole	*Oriolus xanthornus*	LC
22	Blackwinged Stilt*	*Himantopus himantopus*	LC
23	Blossom Headed Parakeet*	*Psittacula cyanocephala*	LC
24	Blue Rock Thrush*	*Monticola solitrius*	LC
25	Blue-faced malkoha	*Phaenicophaeus viridirostris*	LC
26	Brahminy starling	*Sturnus pagodarum*	LC
27	Bronzewinged Jacana*	*Metopidius indicus*	LC
28	Brown Fish Owl*	*Bubo zeylonensis*	LC
29	Cattle egret	*Bubulcus ibis*	LC
30	Chestnut-headed bee-eater	*Merops leschenaulti*	LC
31	Chestnut-tailed starling	*Sturnus malabaricus*	LC
32	Collared Bushchat*	*Saxicola torquata*	LC
33	Common babbler	*Turdoides caudatus*	LC
34	Common Coot*	*Fulica arta*	LC
35	Common flame back	*Dinopium javanense*	LC
36	Common Hoopoe	*Upupa epops*	LC
37	Common iora	*Aegithina tiphia*	LC
38	Common myna	*Acridotheres tristis*	LC
39	Common sandgrouse*	*Pterocles exustus*	LC
40	Common tailorbird	*Orthotomus sutoris*	LC
41	Coppersmith barbet	*Megalaima haemacephala*	LC
42	Crested Hawk-Eagle*	*Spizaetus cirratus*	LC
43	Crested Lark*	*Galerida cristata*	LC
44	Crested serpent eagle*	*Spilornis cheela*	LC
45	Crested tree-swift	*Hemiprocne coronata*	LC
46	Darter*	*Anhinga rufa*	NT
47	Dusky Crag Martine*	*Hirundo concolor*	LC
48	Emerald dove	*Chalcophaps indica*	LC
49	Eurasian collared dove	*Streptopelia decaocto*	LC
50	Eurasian eagle owl	*Bubo bubo*	LC
51	Eurasian golden oriole	*Oriolus oriolus*	LC
52	Goldenbacked Woodpecker*	*Dinopium benghalense*	LC
53	Greater coucal	*Centropus sinensis*	LC
54	Greater racket-tailed drongo	*Dicrurus paradiseus*	LC
55	Green bea-eater	*Merops orientalis*	LC
56	Green Pigeon*	*Treron phoenicoptera*	LC
57	Greenish warbler	*Phylloscopus trochiloides*	LC
58	Grey nightjar	*Caprimulgus indicus*	LC
59	Grey Tit*	*Parus major*	LC

60	House crow	*Corvus splendens*	LC
61	Indian Grey Hornbill*	*Buceros birostris*	NT
62	Indian Moorhen*	*Gallinula chloropus*	LC
63	Indian pitta	*Pitta brachyura*	LC
64	Indian robin	*Saxicoloides fulicata*	LC
65	Indian roller	*Coracias benghalensis*	LC
66	Indian Wren-warbelr*	*Prinia subflava*	LC
67	Jungle prinia	*Prinia sylvatica*	LC
68	Large Cuckoo Shrike*	*Coracina novaehollandiae*	LC
69	Large-billed crow	*Corvus macrorhynchos*	LC
70	Laughing dove	*Streptopelia senegalensis*	LC
71	Lesser coucal	*Centropus bengalensis*	LC
72	Little Cormorent	*Phalacrocorax niger*	LC
73	Little Egret*	*Egretta garzetta*	LC
74	Lorikeet*	*Loriculus vernalis*	LC
75	Loten's sunbird	*Nectarinia lotenia*	LC
76	Malabar Pied Hornbill*#	*Anthracoceros coronatus*	NT
77	Malabar-whistling Thrush*	*Myiophonus horsfieldii*	NT
78	Mottled wood owl	*Strix ocellata*	LC
79	Night Heron*	*Nycticorax nycticorax*	NT
80	Nilgiri Verditer Flycatcher*#	*Muscicapa albicaudata*	NT
81	Nilgiri-laughing Thrush*#	*Garrulux cachinnans*	EN
82	Open-billed stork*	*Anastomus oscitans*	LC
83	Oriental honey-buzzard	*Pernis ptilorhyncus*	LC
84	Oriental magpie robin	*Copsychus saularis*	LC
85	Oriental white-eye	*Zosterops palpebrosus*	LC
86	Painted stork *	*Mycteria leucocephala*	NT
87	Pallid harrier	*Circus macrourus*	NT
88	Pheasent-tailed Jacana*	*Hydrophasianus chirurgus*	LC
89	Pied bushchat	*Saxicola caprata*	LC
90	Pied cuckoo	*Clamator jacobinus*	LC
91	Pied harrier	*Circus melanoleucos*	LC
92	Plain Flowerpecker	*Dicaeum concolor*	LC
93	Plain prinia	*Prinia inornata*	LC
94	Pond Heron*	*Ardeola grayii*	LC
95	Purple sunbird	*Nectarinia asiatica*	LC
96	Purple-rumped sunbird	*Nectarinia zeylonica*	LC
97	Red Munia*	*Estrilda amandava*	LC
98	Red Turtle Dove*	*Streptopelia tranquebarica*	LC
99	Redheaded Merlin*	*Falco chicquera*	LC
100	Red-vented bulbul	*Pycnonotus cafer*	LC
101	Red-wattled Lapwing	*Vanellus indicas*	LC
102	Red-whiskered bulbul	*Pycnonotus jocosus*	LC
103	River Tern*	*Sterna aurantia*	LC

104	Rufous treepie	*Dendrocitta vagabunda*	LC
105	Rufous Woodpecker*	*Micropternus brachyurus*	LC
106	Scaly-breasted munia	*Lonchura punctulata*	LC
107	Scavenger Vulture*	*Neophron percnopterus*	EN
108	Shama*	*Copsychus malabaricus*	LC
109	Shikra	*Accipiter badius*	LC
110	Short-toed Eagle*	*Circaetus gallicus*	LC
111	Small Kingfisher*	*Alcedo atthis*	LC
112	Spoonbill*	*Platalea leucorodia*	NT
113	Spot billed pelican*	*Pelecanus philippensis*	NT
114	Spotted Babbler*	*Pellorneum ruficeps*	LC
115	Spotted dove	*Streptopelia chinensis*	LC
116	Spotted owlet	*Athene brama*	LC
117	Tawny Eagle	*Aquila rapax*	LC
118	Thick-billed flowerpecker	*Dicaeum agile*	LC
119	Velvet fronted nuthatch	*Sitta frontalis*	LC
120	Western Crowned Warbler	*Phylloscopus occipialis*	LC
121	White Ibis*	*Threskiornis aethiopica*	NT
122	White necked Stork*	*Ciconia episcopus*	LC
123	Whitebacked Munia*	*Lonchura striata*	LC
124	Whitebacked Vulture*	*Gyps bengalensis*	CE
125	Whitebellied Tree Pie*	*Dendrocitta leucogastra*	LC
126	Whitebrested Waterhen*	*Amaurornis phoenicurus*	LC
127	White-browed bulbul	*Pycnonotus luteolus*	LC
128	White-cheeked barbet	*Megalaima viridis*	LC
129	White-throated kingfisher	*Halcyon smyrnensis*	LC
130	Wryneck*	*Jynx torquilla*	LC
131	Yellow wagtail	*Motacilla flava*	LC
132	Yello-wattled Lapwing*	*Vanellus malabaricus*	LC
133	Yellowbacked sunbird*	*Aethopyga siparaja*	LC
134	Yellow-billed babbler	*Turdoides affinis*	LC
135	Yellow-browed bulbul	*Lole indica*	LC
136	Yellowheeked Tit*	*Parus xanthogenys*	LC
CE : Critically endangered; EN : Endangered; NT : Near threatened; LC : Least concern; *Reported by Malik (2004).			

Appendix 8: Butterflies recorded in the study area			
No	***Common name***	***Scientific name***	***Status***
Family i. Papilionidae			
1	Common rose	*Atrophaneura aristolochiae*	-
2	Common mime	*Chilasa clytia*	Shed*. I
3	Common mormon	*Papilio polytes*	-

4	Crimson rose	*Atrophaneura hector*	Shed. I& Endemic
5	Lime butterfly	*Papilio demoleus*	-
6	Common banded peacock	*Papilio crino*	Endemic
7	Blue mormon	*Papilio polymnestor*	Endemic
Family ii. Pieridae			
8	Common gull	*Cepora nerissa*	Shed. II
9	Common jezebel	*Delias eucharis*	-
10	Yellow orange tip	*Ixias pyrene*	-
11	White orange tip	*Ixias Marianne*	-
12	Common emigrant	*Catopsilia Pomona*	-
13	Common grass yellow	*Eurema hecabe*	-
14	One spot grass yellow	*Eurema andersoni*	-
15	Three spot grass yellow	*Eurema blanda*	-
16	Crimson tip	*Colotis danae*	-
17	Small grass yellow	*Eurema brigitta*	-
18	Mottled emigrant	*Catopsilia pyranthe*	-
19	Pioneer	*Belenois aurota*	-
20	Common wanderer	*Pareronia valeria*	-
21	Small salmon arab	*Colotis amata*	-
22	Large salmon arab	*Colotis fausta*	-
23	Indian cabbage white	*Pieris canidia*	-
24	Psyche	*Leptosia nina*	-
25	Joker	*Byblia ilithyia*	-
26	Chocolate pansy	*Junonia iphita*	-
27	Common leopard	*Phalanta phalantha*	-
28	Common castor	*Ariadne merione*	-
29	Angled castor	*Ariadne ariadne*	-
30	Blue pansy	*Junonia orithya*	-
31	Yellow pansy	*Junonia hierta*	-
32	Lemon pansy	*Junonia lemonias*	-
33	Grey pansy	*Junonia atlites*	-
34	Danaid eggfly	*Hypolimnas misippus*	-
35	Anomalous nawab	*Polyura delphis*	-
36	Common nawab	*Polyura athamas*	-
37	Common sailer	*Neptis hylas*	-
38	Common evening brown	*Melanitis leda*	-
39	Common tree brown	*Lethe rohria*	-
40	Common bush brown	*Mycalesis perseus*	-
41	Dark blue tiger	*Titumala septentrionis*	-
42	Plain tiger	*Danaus chrysippus*	-
43	Striped tiger	*Danaus genutia*	-
44	Blue tiger	*Tirumala limniace*	-
45	Common crow	*Euploea core*	Shed. IV
46	Glassy blue tiger	*Parantica aglea*	-

47	Tawny coster	*Acroea violae*	-
48	Double-banded crow	*Euploea sylvester*	Endemic
Family iv. Lycaenidae			
49	Common pierrot	*Castalius rosimon*	Shed. I
50	Pale grass blue	*Pseudozizeeria maha ossa*	-
51	Red pierrot	*Talicada nyseus*	-
52	Zebra blue	*Syntarucus plinius*	-
53	Gram blue	*Euchrysops cnejus*	-
54	Yamfly	*Loxura atymnus*	-
55	Plum judy	*Abisara echerius*	-
Family v. Hesperiidae			
56	Common banded awl	*Hasora chromus*	-
57	Brown awl	*Badamia exclamationis*	-
58	Indian skipper	*Spialia galba*	-
59	Common grass dart	*Taractrocera maevius*	
*Schedule of Wildlife Protection Act 1972			

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