Experimental demonstrations in Himalayan Study area

INTRODUCTION

Soil organisms are an integral part of agricultural and forestry ecosystems; and they play a critical role in maintaining soil health, ecosystem functions and production. Each organism has a specific role in the complex web of life in the soil.

The sustained use of the land is dependent upon a healthy biotic community that provides critical processes and ecosystem services. The current technologies and development support for increased agricultural production have largely ignored this vital management component. The improved management of soil biota could play an important role in maintaining soil quality and health and also achieving the goals of achieving higher agricultural production, food security and sustainable land use . The interacting functions of soil organisms and the effects of human activities in managing land for agriculture and forestry affect soil health and quality. These attributes are chiefly those associated with the soil biota. Soil biodiversity is vital for the continued capacity of the soil to support crop. It is well known that land management practices alter soil conditions and the soil community of micro-, meso- and macro-organisms. The structure of soil communities is largely determined by ecosystem characteristics and land use systems. The functions of soil biota are central to decomposition processes and nutrient cycling.

Management strategies, such as crop rotations and use of crop residues as manure, soil quality, which in turn tend to reduce the number of soil arthropods. Farming practices modify soil life including the total number of organisms, the diversity of species and the activity of the individual organisms and the aggregate functions of soil biota. These changes can be beneficial or detrimental to the soil biota and its functions and its regenerative capacity. Farming practices that minimize soil disturbance and return plant residues to the soil, and crop rotation, allow slowly rebuilding and restoring soil organic matter. The mix of soil organisms in the soil also partially determines soil resilience, the desirable ability of a given soil to recover its functions after a disturbance such as fire, compaction and tillage.

Below ground soil faunal diversity is an essential component of for good health of the soil. Soil biota is extremely rich and comprises a high proportion of diversity in most of the agroecosystems. Despite their crucial role in ecosystem functioning, they are poorly known. Anthropoid activities are largely responsible for disturbing the ecological balance of the ecosystem through landscape modification and agriculture intensification. Soil organisms are dependent upon organic matter largely derived from the vegetation cover of the site (therefore there exists a link between above ground and below ground soil biodiversity. Either the farmers or agriculturalists seldom link soil degradation to depletion of the soil fauna. Soil macro invertebrates affect the soil process and cause important modification in soil bio environment with potentially high implication in nutrient limited soils. Species diversity as well as composition of earthworm communities is significantly influenced by the land use – land cover change. In Central Himalaya a mosaic of sacred reserved forest, secondary succession pine forests and a mixture of two characterize the region. Settled crop livestock mixed farming is the major agriculture land use here. The present study therefore is an attempt to evaluate the impact of changed land use cover as well as quality of organic input and water management on soil faunal community structure. Central Himalayas represents the region that was once covered with primary forest but now has a mosaic of disturbed and degraded land uses due to anthropogenic activities, soil erosions, landslides, intensive agriculture practices and a few sparsely distributed patches of climax forests. This region therefore forms an ideal location to study the impact of degradation of natural vegetation /subsequent regeneration of forests and the impact of forest linked crop live stock mixed rainfed / irrigated agricultural management practices on soil faunal biodiversity. Climax forest here has been considered as reference non-impacted/less impacted ecosystem to compare the level of loss or the change in soil faunal diversity.

Description of study site

The study was done in Chamoli district of Uttranchal state of Garhwal Himalayas)(30^{o} 27'N, 79 ^{o} 5'E)The rocks of the area are colored quartzite asscociated with micaceous phyllite and clay stone. The soils are mostly brown forest and podzolic and quartzite in origin . The landscapes in this agro ecological region have a mosaic of natural and human managed ecosystems. The ecosystems thus identified, impacted by various factors will be compared with the reference non-impacted or less impacted ecosystems to compare the level of loss or change in soil faunal diversity. Representative natural and agricultural eosystems differentiated in the land scape were identified as Representative of the natural and agro ecosystems differentiated in the landscape area identified are i) Climax forest ,ii) Mixed forest ,iii) Secondary successional pine forest, iv) Rainfed agroecosystems a) receiving pine based farmyard manure b) receiving oak based farmyard manure v) Irrigated agro ecosystems a) receiving pine based farmyard manure and chemical fertilizers b) receiving oak based farmyard manure and chemical fertilizers (Table 1) The details of the crop rotation as well as cropping pattern under rainfed agroecosystem has been described in (Fig. A 1)

(i) Sequence of changes in land use and management practices was determined based on the government records and information extracted through participatory discussions.

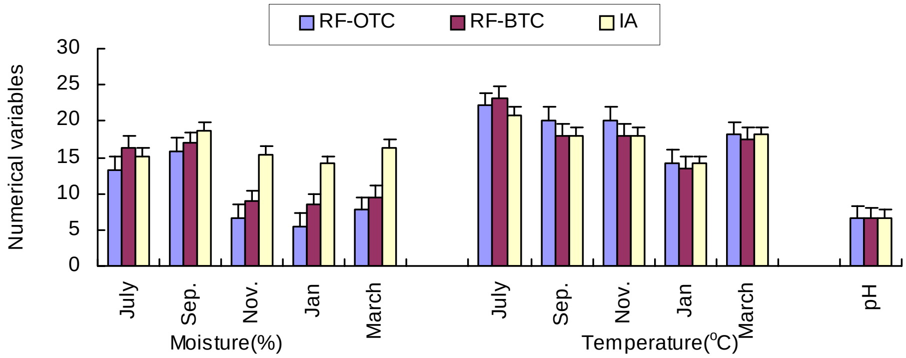

Fig2A.Fluctuation in Soil moisture , Temperature as w ell as pH distribution under different agriculture management Practices RA-OTC rainfed agriculture outside tree canopy;RA-BTC rainfed agriculture below tree canopy;IA irrigated agriculture .

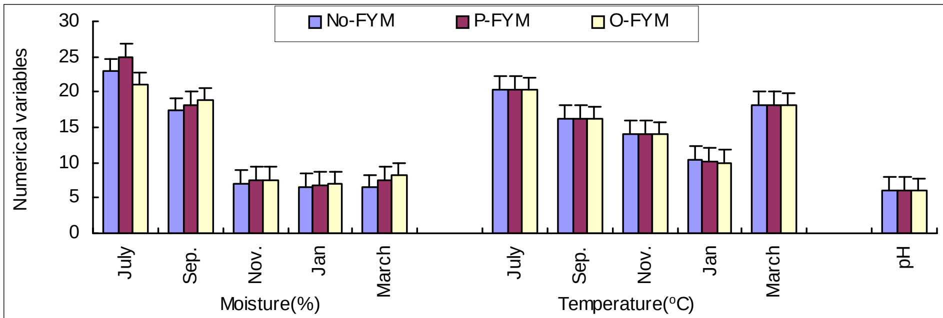

Fig2MB.Fluctuation in Soil moisture , Temperature as w ell as pH distribution under different addition of plant residues additions as Farmyard manure to the soil FYM Farmyard manure;P-FYM Pine based farmyard manure;O-FYM Oak based Farmyard manure.

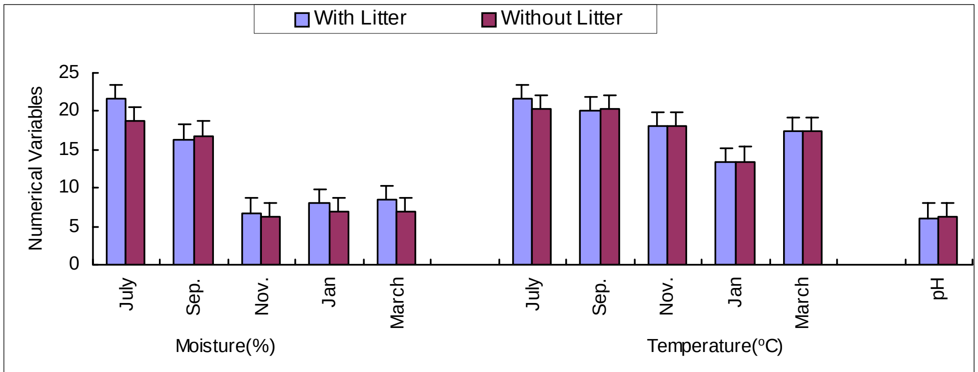

Fig2C.Fluctuation in Soil moisture , Temperature as well as pH distribution under plots With removal of litter from forest floor as well as Without removal of Litter from forest floor.

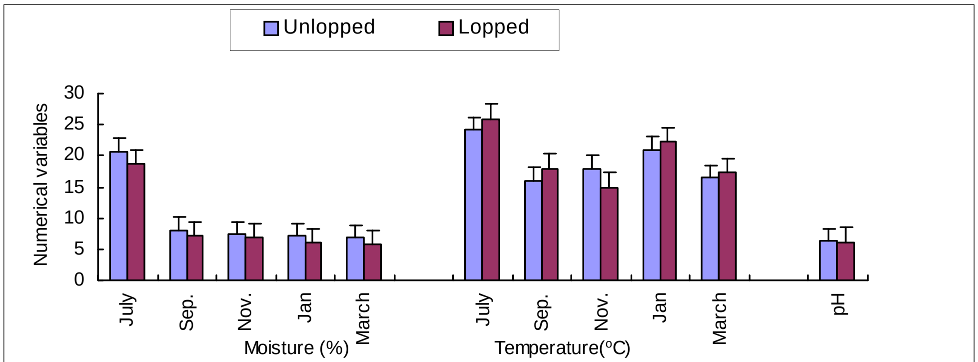

Fig2D Effect of practice of lopping of tree branches on fluctuation in Soil moisture , Temperature as well as pH distribution .

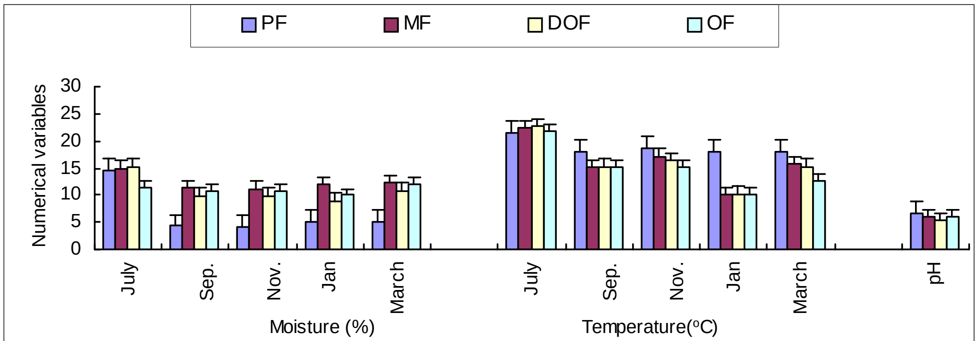

Fig2E Effect of degradation of natural ecosystem on fluctuation in Soil moisture , Temperature as well as pH distribution .

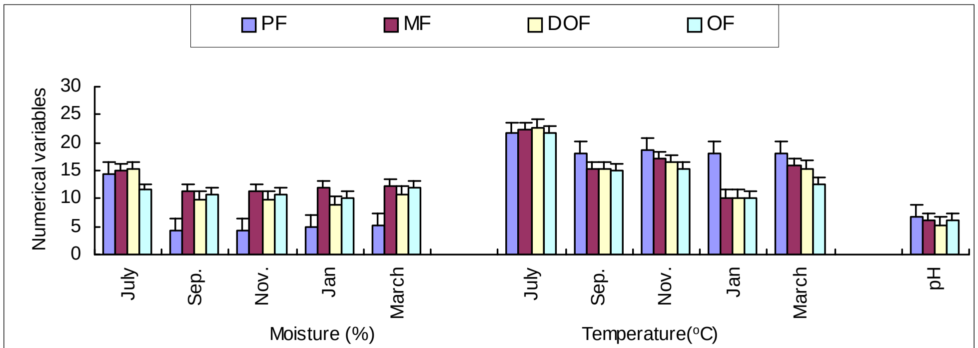

Fig2E Effect of degradation of natural ecosystem on fluctuation in Soil moisture , Temperature as well as pH distribution .

Fig. A1 Crop rotation as well as cropping pattern under rainfed agroecosystems in garhwal Himalayas

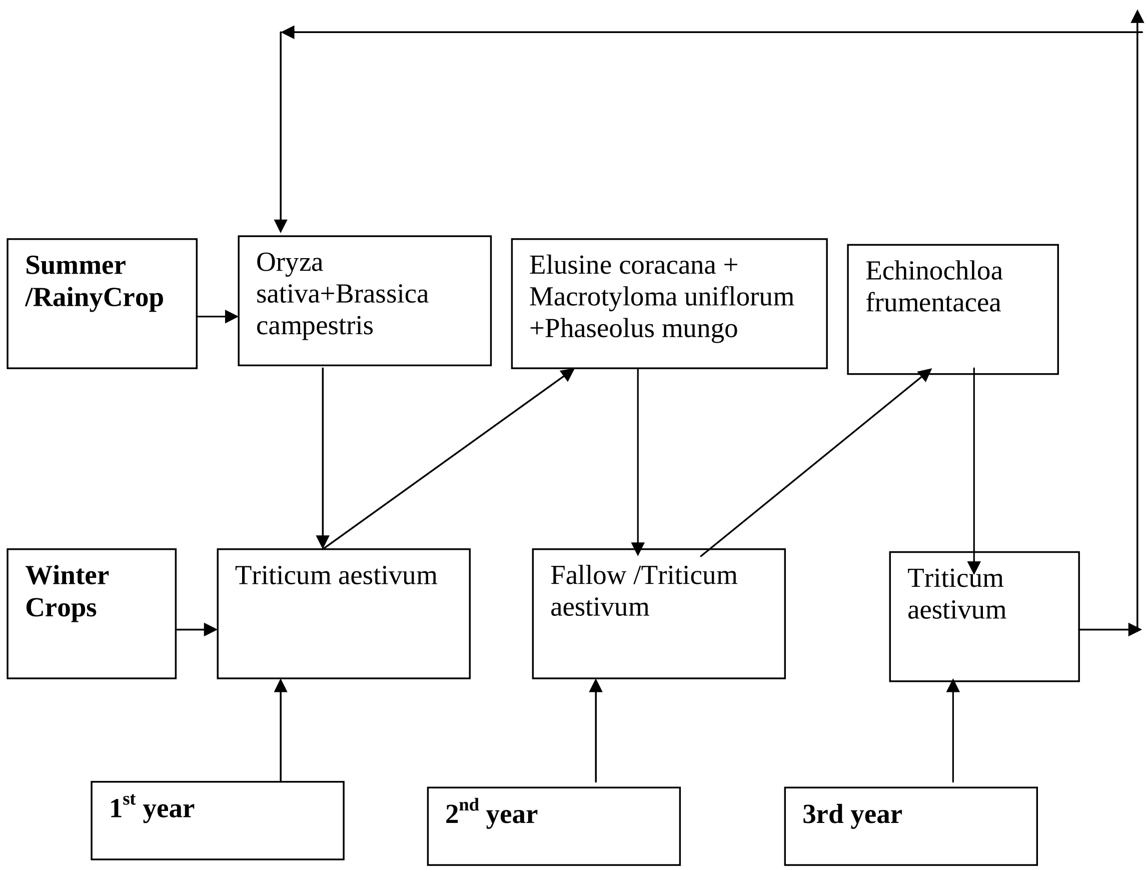

TABLE 1 Salient fetures of land use types in the ecoregion under study.

Location of site	Chamoli distt, Uttranchal State, Garhwal Himalayas)India.(30^{o} 27'N, 79 5'E)
Elevation	1200-1500m (amsl)
Climate	Cool Temperate Winter (Dec – March)16^{a} C mean temperature Summer (April –June) 25.4^{a} C " " Monsoon (July- Oct) 1700 mm annual rainfall
Climax vegetation	Moist deciduous broad-leaved sub temperate climax forest.
Climax forest exposed to fire	Same as above but exposed to fire which caused extensive burn of the litter layer,
Pine and broad-leaved mixed forest.	Mixed forest which is exposed to perturbations like grazing and anthropogenic activities
Pine forest	Naturally regenerating secondary successional conifer forest ,exposed to disturbances like fire ,lopping of logs for fire wood ,grazing by cattle and removal of litter**.**
Degraded ecosystems	Deforested site. These are highly degraded and rocky due to loss of topsoil with poor vegetation cover.
Plantation (Degraded natural ecosystems)	THE ecosystem was subsequently reclaimed and plantation done.
Highly degraded abandoned agricultural terraces	Deforested site, which was used for agricultural purposes and subsequentally, abandoned. These are highly degraded due to animal grazing and also due to loss of top soil
Plantations (highly degraded agriculture terraces)	The agroforestry practices are being followed here since last fifteen years with the purpose to reclaim the degraded soil.
Agricultural practices	Forest linked crop- livestock mixed upland farming
Soil fertility management practices	**Rainfed Agro ecosystems.** Upland farming practiced by 80% of farmers. Input: Pine and Oak based Farm Yard Manure. **Irrigated Agroecosystems Practiced in the valleys, Inputs: Pine and Oak based Farm Yard Manure / Inorganic fertilizers .**
Crops and cropping practices	Irrigated Agroecosystems:, Rice (Summer ,Rains) and Wheat(Winter) crops are taken over a period of One year on rotational basis.Rainfed Agro ecosystems: 4-5 crops taken over a period of 3 years, Trees planted on the margin of terraces

Land Management practices such as, crop rotations and use of plant residues and manure, poor vegetation cover, and/or lack of plant litter covering, lopping of trees can alter soil conditions. This will then alter soil habitats and the food web as well as soil quality, which in turn could alter the structure of soil communities of soil fauna.

To test these hypotheses some experiments were set up at plot level(1X1M2)(Three Replicates for each treatment) on each site to verify the above statements

Besides the above-mentioned sites some other experiments are in progress to emphasize the localized changes that affect the structure as well as function of the soil macrofauna and these are as follows

AGRICULTURE

1. **Rainfed i) Below Tree Canopy, ii) Outside Tree Canopy iii) Irrigated agriculture**

The common practice in rain fed agriculture is to grow trees on the terraces which provide a microclimate to the soil fauna for their distribution, To see the effect of microclimatic variations that occur under these agroforestry trees grown on terraces in rainfed agriculture. Experiments were set up both under the tree canopy in the rain fed agro ecosystem as well as outside the tree canopy the soil fauna was sampled bimonthly to record any variations arising in soil biota community due to these conditions.

2. **No Farm Yard Manure ii) Pine based farm yard manure iii)Oak Based Farm Yard Manure**

A common practice followed by the traditional farmers in the region is to add farmyard manure to their fields as a mean to improve soil fertility. Depending upon the availability of forest closeness to the village the farmers use either Pine based farmyard manure or Oak based farmyard manure. There fore to see the effect of addition of these three types of manures on the soil fertility level and also on the availability of various group of soil fauna three set of experiments each with three replicate have been set up a) Three plots with addition of pine based farm yard manure b) Three plots with oak based farm yard manure c) Three plots with no manure and which will act as control to compare the results obtained due to addition of these FYM. Vermicompost units have been set up to to compare the efficiency of locally available earthworm species for producing vermicompost and with exotic species.

3. **Plot With Lopping done ii) Plots Without Lopping Done**

Lopping is a common practice traditionally followed by the local people to extract the fodder as well as firewood without completely cutting the forest. Therefore to study the lopping effect on the soil fauna Experiments were set up on the three replicate plots where the trees were not lopped and these were compared with the plots where lopping was done. The soil fauna was sampled bimonthly to observe the impact of lopping practices on soil fauna a) where no lopping is practiced b) Plots where lopping is done.

4. With litter ii) Without litter

Since the villagers remove the forest litter and carry it home for either fodder purposes or to be used as a farm yard manure therefore ,to study the effect of litter removal on the distribution of soil fauna 2 sets of replicate experimental plots have been prepared a) Three replicate plots where litter was present. b) Three replicates plots where litter was completely removed i.e litter was left untouched and this was compared with plots where litter was completely removed, care was taken to ensure that no litter was present in these plots, the soil fauna was sampled bimonthly to record any variations arising in soil biota community due to these conditions.

5. Degraded as well as reclaimed agricultural/Natural ecosytems

Experimental plots were set up in the degraded agricultural terraces as well as in the reclaimed agricultural terraces to study the effect of change in community structure as well as diversity of soil fauna due to the first degradation affect and subsequently on recolonisation by various soil fauna as a result of reclamation processes. Similar experiment was also done in the naturally degraded forest as well as in the reclaimed forest. This was done to compare any variations that may arise in the community structure of soil biota as a result of different land management practices.

6. I**) Forest Litter ii) Pine based farm yard manure iii) Oak based farm yard manure litter IV) Pine based Vermicompost V) Oak based Vermicompost**

Experimental plots (Three replicates) were set up to study the effect of each of the four composts used on the growth and productivity of pea crop. The study would be useful in assessing as to weather their occurs any variation between the use of each of these manure on the crop yield or weather the variation between the four treatments was not significantly different. The study also includes the effect of each of the four composts used on the diversity and distribution soil faunal community structure.

METHODOLOGY

Sequence of changes in land use and management practices was determined based on the government records and information extracted through participatory discussions.

- In each ecosystems and land use types 50x50m^2 experimental plots were marked. Field sampling of soil fauna i.e Earthworms/Macroarthropods was done using hand-sorting methods by placing ten sampling points along at 5m interval randomly along a 50m line transect using soil monolith of 25x25x30cm^3 (Anderson and Ingram 1993). Earthworms were preserved in 5% formalin whereas soil arthropods preserved in 95% alcohol mixed with few drops of glycerin added to it for taxonomical identification.(Table2)

- **Pitfall Traps**

8 to 10 individual pitfall traps were established and trapped organisms preserved in 70-90% isopropyl (rubbing alcohol).

- **Berlese Funnels**

Berlese funnels were used to extract Acarina and collembola from litter and soil samples using soil corers. These were preserved in absolute alcohal with few drops of glycerine added to them.

- **SOIL SAMPLING AND CHARACTERISTICS**

Composite soil samples collected monthly from each of the natural ecosystems and along the cropping cycle in agroecosystems.(Table. 2)

- Physical analysis: Soil Temperature (°C), Soil Moisture (% oven dry weight at 105 °C),Texture (% Sand, Silt, Clay,) Hydrometer method., Bulk Density(gm/cm^3), pH(1:2.5 Soil:Water)
- Chemical Analysis:Total N (Kjeldahl method), Organic C (Walkey Black method) Exchangeable Ca^{2+} , Mg^{2+} (EDTA titration)and Na^+, K^+(flame photometer), Extractable Phosphorus, Spectrophotometrically by Molybdenum blue method after extraction with $NaHCO_3$ solution. Nutrients estimated in freshly frozen earthworm tissues by microkjeldahl method. Vegetation Analysis and litter production 20 random quadrate (1x1m^2) for herbs and 20 (5x5m^2) random quadrates for shrub and trees considered. IVI the importance value index will also be calculated..

STATISTICAL ANALYSIS

1. Earthworm/Arthropod density will be done as(Individual / Area,).
2. Earthworm/Arthropod species dominance calculated as individual of a species as a function of total number of all the species under different field conditions.
3. Sample standard error will be calculated as the standard error of the mean
4. To test the significant variation in the density and biomass of Earthworm/Arthropod species, and soil characteristics across different sampling sites, Kruskal Wallis test of variance will be done followed by New Manns Keuls Multiple range test for comparison between the sites
5. Seasonal variation in density of earthworms and arthropods at all the sites will also be analyzed using Kruskal Wallis test of variance followed by New Manns Keuls Multiple range test.
6. The relationship between soil parameters and earthworm /arthropod species will be calculated as simple linear regression and correlation coefficient
7. Kolmogrov-Smirnov good of fit test would be used for analyzing the distribution of earthworms'/ arthropods no/m2 vertically in top O–40cm of soil.

8. Species diversity will be measured using Hurlbert Probability of interspecific encounter (Hurlbert 1971) PIE= Sigma (n i / n) [(n – ni) / (n -1)] where n= number of all individuals in the sample ni=number of individuals of a species in the sample s= total number of species.

Categorization of earthworms/Soil Arthropods

- Based on their place of origin Earthworms would be classified as Endemic or Exotics.
- Based on their functional guild analysis earthworms will be classified according to their feeding habits and distribution in soil profile as
- Endogees – Soil dwellers/feeders
- Epigees - Litter dwellers
- Anecics - Deep burrowing species /litter feeders

- TABLE 2. Description of Methodology

Variables	Comment	Units
Climate	Mean monthly temperature, Rainfall; Soil moisture,Soil Temperature,	C; mm ; C,
Soils	Mechanical analysis(Hydrometer) pH ; Organic Carbon (walkey black) ; Total N ; Exchangeable Ca,Mg,K 1N NH_4OAc at pH7; Extractable P ,Bicarbonate, pH 8.5	(%) 1:2.5water ; (%) (%) ; me/100gm; mg/kg
Vegetation	Phytosociology ; Density; DBH; Basal Area	No/ha, meters, m^2/hactare
Soil Fauna Earthworms/Hymenoptera/Coleoptera/ Coleoptera Larvae /Isoptera/Dermaptera/Arachnida	Density and Biomass (Hand sorting method; 10 [3] $25x25x30cm^3$	No/m^2
Collembola Entomobryomorphids,Sminthurids, /Acarina /Diptera Larvae.	Pitfall method; Berlese funnel method using soil corer (5cm diameter/7cm length) 10 replicates	No/m^2
Acarina , Collembola(Podumorphs)	Berlese funnel method using soil corer (5cm diameter/7cm length)10 replicates; Soil/litter layers	No/m^2

Table 3. Physico-chemical characteristics of soils under varied land use types (±SE)

Land Use	Sand (%)	Silt (%)	Clay (%)	pH	Organic carbon (%)	Nitrogen (%)	Ca (meq/100gm)	K (meq/100g)
Climax Vegetation	14.7 ±1.5	62.3 ±2.5	23 ±1.5	5.1	2.13 ±0.5	0.22±0.02	3.82±0.2	0.34±0.01
Agroecosystems Oak based FYM								
Irrigated	16.3 ±1.4	49.70 ±3.8	34 ±2.1	6.2	2.8 ±0.2	0.21±0.01	4.72±0.3	0.27±0.02
Rainfed	19.4 ±1.3	47.80 ±3.8	32.8 ±1.5	6.2	2.2 ±0.21	0.24±0.01	5.42±0.3	0.38±0.01
Oak pine Mixed forest	28.7 ±1.6	48.78 ±2.9	22.5 ±1.4	5.8	2.7 ±0.5	0.24±0.01	4.48±0.4	0.23±0.01
Pine forest	15.7 ±1.2	46.2 ±3.7	38.3 ±1.8	5.6	1.5 ±0.13	0.13±0.01	2.69±0.1	0.34±0.02
Agroecosystems Pine Based FYM				6.1				
Irrigated	26 ±1.3	47 ±3.2	27.9±	6.1	2.60 ±0.14	0.28±0.02	7.2±0.4	0.36±0.01
Rainfed	21 ±1.6	48.2 ±2.7	38.2±	6.2	1.5±	0.17±0.01	3.61±0.2	0.21±0.01

Results and Discussion

Changes in land use pattern and vegetation structure resulted in significant differences in soil microhabitat conditions (Table. 3) (Fig.2A,B,C,D,E,F)and therefore modification of soil properties. These in turn cause alteration of soil macro fauna.

Effect of agricultural management practices on Earthworms

A total of five species were present in both the rain fed as well as irrigated agroecosystems . The rainfed agroecosystems were more preferred site for the colonization by the earthworms. Drawida nepalensis was a successful colonizer of all the three agroecosystem, however their relative density as well as the biomass values varied with in the agriculture system. D.nepalensis had higher density ($P<0.05$)as well as biomass values ($P<0.05$) in the rainfed agriculture outside the tree canopy (hereafter referred to as RFOTC) followed by the Octochetona beatrix .In the rainfed agriculture under the tree canopy (hereafter referred to as RFBTC) Metaphire birmanica was dominant and had significantly higher density as well as biomass values followed by D.nepalensis .Metaphire anamola as well as Amynthas alexandrii also had higher density as well as biomass valus here when compared to RFOTC and irrigated agriculture. Amynthas alexandrii was absent from the irrigated agriculture whereas all other species had much lower density as well as biomass values. The total density as well as biomass values was significantly higher in the RFBTC site as compared to the RFOTC plots and Irrigated sites. The density as well as biomass values of all the species had significantly higher abundance and biomass values during the WET months (JUNE-OCT) as Compared to the dry months (NOV-MARCH) .The higher density as well as the biomass values for earthworm species under RFOTC could be due to low disturbances in the soil and also lack of any perturbation pressure here however further details could only be given once the soil analysis is done on all the sites.(Fig.1a.b.c.d)

Effect of practice of tree lopping on the Earthworms

Studies done in experimental plots to see the effect of lopping of the trees on earthworms showed that the lopping practices adversaly affected the earthworm community structures .A total of six species A.alexandrii,D.nepalensis ,Metaphire anamola, Metaphire holutii, Lennogaster Sp.and Octochaetona beatrix were present in the unlopped tree plots. The lopping activity resulted in the loss of all the species except A.alexandrii and D.nepalensis This adverse affect of lopping on earthworm community structure could be attributed to the loss of surface litter which is removed as fodder as well as also due to intense disturbance caused by trampling due to lopping activity, further this could also result in the penetration of sunlight causing increased temperature and low moisture but this would be confirmed after the soil analysis is done. (Fig. 2a.b.c.d)

Effect of addition of plant residues as Farmyard manure to the soil and subsequently to the earthworms

Colonization of earthworm species was significantly higher ($P<0.05$) the farmyard manure were added to the soil than when no farmyard manure is added as manure. The total species richness did not vary significantly between Oak based Farm yard Manure(hereafter referred to as OBFYM) And the Pine based Farmyard manure(hereafter referred to as PBFYM),but this value was significantly lower in no Farm Yard Manure treatment (hereafter referred to as NFYM).A total Five species A.alexandrii Bimastos parvus ,D.nepalensis ,Metaphire anamola, Metaphire holutii, colonized the sites incorporated with the farm yard manure. Metaphire holutii was more successful colonizer of soil incorporated with oak based farm yard amnure as they had higher density as well as biomass values here but A.alexandrii had higher density but lower biomass values in the (PBFYM).Only A.alexandrii and M.holutii were present in the soils which were not incorporated with any Farm yard manure.this experiment thus emphasized that addition of plant residues into soil help improve the earthworm community structure , analysis of soil as well as plant material would further add to the reason of increase in soil fauna(.Fig 3a.b.c.d.).

Effect of removal of litter from forest floor

Experimental plots were set up to study the effect of removal of litter from forest floor (a common practice adopted by the local farmers in the Himalayas)on the soil fauna .A total of six species A.alexandrii ,D.nepalensis ,Metaphire anamola, Metaphire holutii Lennogaster Sp.and Octochaetona beatrix were recorded from the plots where the forest litter was present.In the plots without any litter all these species were absent . Lennogaster Sp was significantly most abundant numerically($P<0.05$) but D.nepalensis ,M holutii with lower density had significantly higher biomass($P<0.05$) values as compared to the other species. Total density as well as biomass values of earthworm species were significantly higher ($P<0.05$) in the with litter plots than without litter plots. These values were also higher during the wet season than during the dry season. (Fig.4 a.b.c.d.).

Effect of degradation of natural ecosystems

Studies done along a gradient of forest disturbances due to various perturbation pressure sfrom reserved oak forest to secondary successionsl pine forest through transitional mixed forest showed variations in species distribution . A total of five species were recorded from the reserved oak forest *A.alexandrii B.parvus ,Metaphire anamola, Lennogaster Sp and Perionyx.sp. Lennogaster* Sp had significantly higher ($P<0.05$) density here but *M.anamola* having higher biomass values. Fire in the oak forest resulted in the loss of *A.alexandrii, Lennogaster Sp and Perionyx.sp.*.and there was a decline in the density and biomass of the remaining species.D nepalensis was new species which recolonised the degraded forest .Transitional mixed forest consisted of three species *B.parvus ,Metaphire anamola and M.holutii. With M.holutii* having significantly higher density as well as biomass values ($P<0.05$)here as compared to other species.The degraded secondary successional pine forest consisted of four species with *A.alexandrii* colonizing this forest besides other three species present earlier in the mixed forest. *Perionyx sp*.was the only species present during the dry season in the oak forest where as *M.holutii* was present in lower abundance in the mixed forest during the dry season.All other species were absent here during dry season.total density (P<0.05)as well as biomass values(P<0.05) were significantly higher in the reserved oak forests as compared to the degraded pine forest as well as Mixed forests. (Fig.5 a.b.c.d.).

Effect of reclamation of degraded agroecosystems as well forest ecosystem on earthworms

The earthworm species richness as well as abundance(P<0.05) and biomass values(P<0.05) improved significantly in the reclaimed agroecosystems as compared to degraded ecosystems. A.alexandrii ,D.nepalensis ,Metaphire anamola were present in lower abundance in degraded agroecosystem. Reclamation of this ecosystem for a period 15 years led to colonization by epigeic Lennogaster species where as A.alexandrii was absent here. The colonization of reclaimed forest land was much slower when compared to reclaimed agroecosystems. with only A.alexandrii and Metaphire birmanica present here. Metaphire anamola was successful recoloniser of the reclaimed forest land though the density here was much lower. Total density did not vary significantly between the reclaimed as well as degraded forest sites however the biomass values were significantly higher (P<0.05) in the reclaimed forest site. Except for the, D.nepalensis which was present during the dry season in the abandoned agriculture system all other species were absent here as well as in reclaimed sites. The mean density (P<0.05) as well as the biomass values(P<0.05) were significantly higher in the reclaimed agroecosystems as compared to the degraded agroecosystems. In naturally degraded forest systems the mean density values of earthworms did not vary significantly between the degraded as well as the reclaimed ecosystems, but the earthworms had significantly higher biomass (P<0.05) in the reclaimed forests. (Fig.6 a.b.c.d.).

Soil Macroarthropods(Hand sorting Method)

Effect of agricultural management practices on Macroarthropods

Composition of soil macroarthropod community is significantly affected by the agricultural practices. The total density of soil fauna was significantly higher(P<0.05) in the rainfed agriculture below the tree canopy as compared to the rainfed agriculture outside the tree canopy, as well as in the irrigated agro ecosystem. Coleoptera (Beetles) had significantly higher density (P<0.05) as well as biomass values (P<0.05) in the RABTC as compared to the RAOTC agro ecosystems,Coleoptera larvae as well as Orthoptera(Grass hoppers/Crickets) had higher density (P<0.05) as well as biomass values (P<0.05) in the RAOTC agro ecosystems and this could be because the Coleopteran larvae as well as Orthoptera feed on the plant material which was abundant in the cropped agro ecosystems.Only coleopteran larvae were present in RAOTC plots during the dry season with all the other species having greatly reduced density as well as biomass values at all the three sites((Fig.7 a.b).

Effect of addition of plant residues as Farmyard manure to the soil and subsequently to the soil arthropods.

The addition of Farm yard manures had positive affect on the soil macroarthropods as could be seen through their significantly higher density ($P<0.05$) as well as biomass values ($P<0.05$) in the With Farm yard manure treatments than in the plots Without farm yard manure treatment. The plots without FYM had very low abundance of Hymenoptera(Ants) ,coleoptera larvae ,Isoptera(Termites) as well as Orthoptera ,with Hymenoptera being numerically most abundant here. The response of the soil macrofauna however varied with the type of farmyard manure used, thus the plots receiving OBFYM had significantly higher density ($P<0.05$) as well as biomass ($P<0.05$) of macroarthropods when compared to plots treated with PBFYM. Biomass of coleopteran larvae was significantly higher ($P<0.05$) in the plots receiving OBFYM as well as PBFYM where as Hymenoptera were numerically more abundant($P<0.05$) in plots receiving PBFYM as well as OBFYM,. All other groups except Orthopteras did not vary significantly between plots receiving two types of FYM. All the arthropod groups showed a steep decline in abundance as well as biomass values during the dry season in the experimental plots (Fig.8 a.b).

Effect of removal of litter from forest floor

Composition of soil macrofaunal community is influenced by the presence of litter on the soil surface of the forest. The community structure of soil arthropod in plots With litter was composed of Coleoptera Larvae, Arachnida(Spiders), Coleoptera, Dermaptera(Earwigs), Isoptera, Orthoptera and Hymenoptera. The Hymenoptera were numerically more abundantas ($P<0.05$) compared to the other groups but Coleoptera larvae as well as Coleoptera had significantly higher biomass ($P<0.05$) here. Removal of the forest litter layer led to loss of all the groups except the Hymenoptera, which were numerically more abundant ($P<0.05$) here. As was the case with other experiments all the groups declined significantly seasonally during the dry season. (Fig.9 a.b)

Effect of practice of tree lopping on the Macroarthropods

Though lopping of trees is a process, which is not directly asscociated with the soil disturbance, but this activity also alters the soil fauna indirectly by altering the physico chemical soil properties. The removal of tree canopy leads to the direct penetration of sunlight to the forest floor which in turn alters the soil micro climate and thus affecting the composition of soil macrofauna .The macrofaunal community in the plots without lopped trees was composed of Coleoptera Larvae, Arachnida, Coleoptera, Orthoptera and Hymenoptera ,with Hymenoptera being numerically most abundant ($P<0.05$) here. The lopping of trees resulted in significant decline in the density as well as biomass of these groups. Coleoptera larvae had significantly higher biomass($P<0.05$) in plots with unlopped trees.The higher density of Orthoptera in the lopped plots could be explained as due to the presence of left over dead wood as well as leaves which could serve as a source of food .But this would be confirmed only after the soil as well as plant analysis will be completed (Fig.10 a.b).

Effect of degradation of natural ecosystems on the Macroarthropods

Composition of soil macroarthropod community is significantly influenced by the disturbance as well as conversion of reserved forests to other forest types . In the present study the composition of soil community was significantly influenced by the conversion of reserved oak forest to Pine forest, The reserved forest arthropod community structure was composed of Coleoptera Larvae, Arachnida Coleoptera, Dermaptera ,Isoptera, Orthoptera and Hymenoptera. The disturbance in the Oak forest due to fire resulted in the loss of Dermaptera as well as Isoptera and a significant decline in all other groups. Arachnids as well as Coleoptera larvae had significantly higher density($P<0.05$) as well as biomass values($P<0.05$) in secondary successional pine forest as compared to the transitional mixed forests. Hymenoptera had higher density in the mixed forests. The improved density of Isoptera in the oak fores($P<0.05$) t could be due to the presence on dry wood as well as low soil moisture conditions. favoured by them. Though all other groups had shown a significant decline in the abundance as well as biomass values here. Total density as well as biomass values of soil macroarthropods declined significantly($P<0.05$) along the disturbance gradient from reserved forest to secondary successional pine forest. (Fig.11 a.b)

Effect of reclamation of degraded agroecosystems as well forest ecosystem on the Macro arthropods.

Degradation of productive agroecosystems resulted in the lower abundance as well as biomass values of all the groups i.e Coleoptera Larvae, Arachnida ,Coleoptera, Dermaptera, Isoptera and Orthoptera however the Hymenoptera had significant($P<0.05$) ly higher abundance($P<0.05$) in degraded agroecosystems. Reclamation measures in the agroecosystems resulted in significantimproved($P<0.05$) colonization by coleoptera larvae as well as Coleoptera over a 15 years period after reclamation. Isoptera were present in significantly higher number t($P<0.05$) in the degraded forest sites when compared to the reclaimed forests and this was expected because Isoptera are successful colonizers of degraded ecosystems because of their feeding habits . Orthoptera as well as Coleoptera larvae were successful coloniser of reclaimed forest sites((Fig.12 a.b).

Thus it could be assumed that probably changes in the herbaceous cover with variation in different land use type could explain the variation in macrofaunal composition. Arachnids are primarily secondary consumers and there abundance is dependent on the prey density. Numerical dominance of hymenoptera seem to derive from their adaptation to dry climate condition as well as ability to persist in degraded soils.The coleoptera as well as coleoptera were more abundant in the soils with good amount of vegetation cover as well as least perturbation pressures.Degraded soils had much lower number of coleopteran larvae .These organisms could thus probably be considered as bioindicators showing the soil health but the conclusions can be drawn only after the plant as well as soil analysis are completed.

Effect of agricultural management practices on mesoarthropods(PITFALL METHODS)

In the agroecosystems due to various agricultural practices different collembolan family groups responded differentially to the level of perturbations there . The entomobryomorphids or the spring tails had significantly higher population density (P<0.05) in the rain fed agroeco systems as compared to the irrigated agroeco systems.

Within the rain fed agroecosystems their number was more abundant(P<0.05)under the tree canopy(RFBTC)than outside the tree canopy(RFOTC). This could be attributed to more leaf litter present in RFBTC Plot than in RFOTC plot ,also the perturbation levels here are much less.Podumorphs(Grub like spring tails) also had higher density in the RFBTC plot . Sminthurids(Globular springtails) had much lower population abundance here . The total density of entomobryomorphids was significantly highe r (P<0.05) in the rainfed agroecosysytems when compoared to the irrigated agroecosysytems. Higher abundance (P<0.05) of the coleopteran larvae during dry season in irrigated agriculture could be because of the wheat crop present in the irrigated fields along with the sufficient soil moisture. The coleoptera had significantly higher biomass values(P<0.05) in the rainfed as well irrigated agroecosystems as compared to other groups(Fig.13 a.b).

Effect of addition of plant residues as Farmyard manure to the soil and subsequently to the soil arthropods

The density of entomobryomorphids did not vary significantly between the plots receiving oak based farmyard manure as well as the pine based farmyard manure. Podumorphs however had significantly higher density (P<0.05) as well as biomass values (P<0.05) in experimental plots receiving oak based farmyard manure when compared to the pine based farmyard manure.The total density of collembola were significantly lower (P<0.05) in the plots without farm manure treatment than when compared with the with farm yard manure treatments. Podumorphs were totally absent here .Entomobryomorphids declined significantly(P<0.05) in the abundance during the dry season in all the three plots with podumorphs as well as sminthurids being totally absent here.Hymenoptera had significantly higher biomass(P<0.05) in the plots receiving Pine based farm yard manure as compared to other plots. Thus addition of farmyard manure to the soils improved the soil community structure. (Fig.14 a.b).

Effect of removal of litter from forest floor

The presence of forest litter in the experimental plots had higher abundance (P<0.05) of Entomobryomorphids when compared to plots Without the forest litter layer present. Sminthurids as well as podumorphs are totally absent from the plots without the litter layer treatments indicating the degraded status of the soil. Though the collembola had significantly higher abundance (P<0.05) at all the sites but the Coleoptera in the With litter plots during the wet season and the larvae during the dry season had significantly higher biomass values(P<0.05) . The density of collembola was much lower during the dry season in the experimental plots. Hymenoptera was dominant (P<0.05) in the plots without litter layer during the dry season. (Fig.15 a.b).

Effect of practice of tree lopping on the Mesoarthropods

As has been earlier reported the lopping of the trees not only affected the soil macrofauna communities but it also resulted in the decline of abundance of Entomobryomorphids and Podumorphids this could be attributed to the decline in the amount of litter produced due to removal of the branches. Though collembola were numerically more abundant(P<0.05) in the unlopped sites but here also as in the other cases mentioned earlier coleoptera as well as larvae had higher biomass values(P<0.05) . During the dry season coleoptera had higher biomass(P<0.05) both in the lopped and unlopped tree plots((Fig.16 a.b).

Effect of degradation of natural ecosystems on the Macroarthropods.

The change in the land use pattern with the asscociated change in soil and vegetation cover is refelected in terms of change in collembolan community structure. Abundance of Entomobryomorphids inhabiting litter layer were more abundant (P<0.05) in secondary successional pine forest as compared to the oak forest.both during the wet months as well as the dry season. Podumorphs on the other hand had higher population diversity (P<0.05) in the mixed forest. The disturbance in the oak forest further led to shrp decline in the entomobryomorphids. The Hymenoptera population showed higher abundance(P<0.05)in degraded oak forest and transitional mixed forest when compared to Oak forest as well as pine forest. The entomobryomorphid had lower biomass in the oak forest, which improved significantly in the secondary successional pine forest. Compared to other arthropods during the wet season. However during the dry season these biomass values of collembola declined in the oak forest as well as the pine forest. Hymenoptera were more abundant (P<0.05) in the degraded oak forest as well as pine forest. (Fig.17 a.b).

Effect of reclamation of degraded agroecosystems as well forest ecosystem on soil Meso arthropods

Collembola especially entomobromorphids(were more successful colonizer of reclaimed degraded ecosystems. Relative abundance (P<0.05) of entomobromorphids was more in the reclaimed forest compared to the agroecosystems. The wet season favored growth of entomobromorphids as compared to the dry season. Though collembolan had numerical abundance entomobromorphids in the reclaimed site but the coleoptera had significantly higher biomass entomobromorphids values in both the reclaimed agroecosystem as well as forest systems. During dry season also in the forested ecosystems the coleoptera had significantly higher biomass values (P<0.05). Thus various activities which cause the degradation of ecosystems negatively impacts the community structure of soil biota, the reclamation of degraded sites are slowly recolonised by these organisms. (Fig.18 a.b).

Soil Mesoarthropods(BERLESE FUNNEL METHOD)

Acarina or mites are the characteristics of the stable ecosystems and highly sensitive to disturbances, Podu morphs as well as acarina were more successful colonizer of rainfed agroiecosystems when compared to the irrigated agroecosystems. The agriculture intensification also affected the density as well as distributions of these groups . Within the rainfed agroecosystem the Collembola as well as Acarina were significantly more abundant ($P<0.05$) in RFBTC Plot than in RFOTC plot. Podumorphs were significantly more abundant ($P<0.05$) here than the Acarina indicating presence of well developed porous soil under the RFBTC Plot than in RFOTC plot.during the wet season. However the trend was reversed during the dry season where Acarina had significantly higher abundance($P<0.05$) in the RFOTC Plot than in RFBTC plots, as well as in the irrigated site. This could be because the Acarina are primary consumers and also prefer dry condition which were both provided during the wheat crop. Podumorphs had higher biomass values($P<0.05$) during the wet season at all the sites however Acarina were more dominant and had significantly higher biomass values($P<0.05$) during dry season in RFOTC Plot than in RFBTC plots. Podumorphs had significantly higher biomass values ($P<0.05$) in both dry as well as wet season in RFBTC Plot than in RFOTC plots. (Fig.19 a.b).

Effect of addition of plant residues as Farmyard manure to the soil and subsequently to the soil arthropods

The Podumorphs had significantly higher abundance ($P<0.05$) in the plots with the Oak based Farm yard manure as compared to those plots receiving the Pine based farmyard manure .Dipteran larvae were present only in the soils receiving the Pine based farmyard manure.The Farm yard manure treated soils had lower acarina abundance as compared to the podumorphs .Though these values were higher in PBFYM. Only podumorphs and to a lesser extent Acarina were collected from the FYM treated soils during the dry season. N FYM treated soils were devoid of any decomposer fauna. Podumorphs had significantly higher biomass($P<0.05$) values in OBFYM during the wet season. (Fig.20 a.b).

Effect of removal of litter from forest floor on soil Mesoarthropods

Acarina had significantly higher abundance ($P<0.05$) in the plots With litter layer than Without the litter layer.Podumorphs were also more abundant in With litter layer plots than Without litter layers ,though these values were most abundant during the dry season($P<0.05$) than the wet season .The sminthurids as well as the podumorphs had much lower density during the wet season in the With litter plots Entomobryomorphids on the other hand had higher abundance during ($P<0.05$) the wet season.. Acarina had significantly higher biomass values($P<0.05$) compared to collembola in the with litter plots.both during the wet season as well as the dry season. (Fig.21 a.b).

Effect of practice of tree lopping on the Mesoarthropods

As the effect of lopping of trees adversely affected the soil decomposer fauna with significant decline($P<0.05$) in the abundance of Acarina as well as collembola in the plots where lopping was done.

Both Acarina as well as Podumorphs were significantly more abundan($P<0.05$) t as well as had higher biomass values($P<0.05$) during the dry season in the unlopped experimental plots than in the plots with lopped trees.Sminthurids were present in lower number here. Acarina had significantly higher biomass values($P<0.05$) than the Podumorphs in both lopped as well as unlopped sites. (Fig.22 a.b).

Effect of degradation of natural ecosystems on the Macroarthropods

The effect of degradation of natural forests to secondary successional pine forest resulted in the alteration of soil decomposer fauna .The response of collembolan family group varied with the vegetation cover and land management practices thus Podumorphs were significantly($P<0.05$) more abundant in the degraded pine forest as well as in the mixed forest when compared with oak forest during the wet season where as the reverse was the case for the Acarina which had significantly higher population density($P<0.05$) in the oak forest during the wet season. Acarina were more abundant in the Oak forest as well as in the mixed forest during the dry season.as compared to the Podumorphs. Population density of Podumorphs did not vary significantly between pine forest and the degraded forest between two seasons. Podumorphs had significantly higher biomass values($P<0.05$) during wet season in the pine forest as well as the oak forest. Acarina on the other hand had significantly higher biomass values ($P<0.05$) during dry season in the oak forest .

The fire in oak forest more directly affected Collembola as well as Acarina because of the burn of the litter layer.The recolonisation by the Collembola as well as Acarina occurred six months after the fire. (Fig.23 a.b).

Effect of reclamation of degraded agroecosystems as well forest ecosystem on soil Meso arthropods

Acarina as well as collembola were more successful colonisers of degraded reclaimed agroecosystems as well as reclaimed forests. Podumorphs as well as Sminthurids were more successful in recolonising the reclaimed agroecosystems than the forestlands. Sminthurids which were reported only from the reclaimed agroecosystems indicate the early success ional status of the reclaimed agroecosystems. Acarina on the other hand were present in the higher density ($P<0.05$) as well as biomass values ($P<0.05$) in th e reclaimed forest sites than in the agroecosytems. Thus it can be concluded that Acarina are more abundant in the sites with low moisture content and with lower perturbation pressure that is in the natural ecosystems than the agroecosystems.Thus they are more susceptible to changed land management practices and biomass of earthworm bioindicators to indicate level of soil degradation. (Fig.24 a.b).

Forest Litter ii) Pine based farm yard manure iii) Oak based farm yard manure litter IV) Pine based Vermicompost V) Oak based Vermicompost

Experiments carried out in the pea crops using different types of farm yard manure gave very interesting results on the effect of use of different farm yard manures on the soil faunal community. The response of soil biota differed in the different management practices.

In all the treatments the total soil faunal density was significantly higher during($P<0.05$) the cropping season, which declined subsequently after the harvesting of crop. Collembola had significantly higher population density($P<0.05$) in the Pine Litter based farm yard manure as compared to the other treatments. Entomobryomorphids had significantly higher abundance in the plots receiving ($P<0.05$) PLVC where as Sminthurids had higher density in the plots with the direct incorporation of the forest litterLL. Podumorphids on the other hand had higher population density ($P<0.05$) in the Plots receiving OBFYM as well as OBVC.during cropping with a subsequent decline thereafter.In the PLFYM plots was there number was much higher before the cropping period with a subsequent decline thereafter . Acarina on the other hand was affected by the cropping operations as they had significantly higher density at all the plots before the cropping was initiated but subsequently during the cropping their density declined significantly The abundance of Acarina was significantly higher in the plots receiving PLVC as compared to the other treatments. The coleoptera larva were more abundant ($P<0.05$) during the cropping season in plots incorporated with OBFYM ,PFYM and PLVC and their density declined significantly subsequent to cropping season . The density of coleoptera larvae did not vary significantly between the the plot treatments mentioned earlier. Hymenoptera had significantly higher population density ($P<0.05$) during cropping in the PLVC plots.Their number declined subsequent to crop harvest. Arachnids also had significantly higher density during cropping at all the experimental plots but their density did not vary significantly between different treatments. (Fig25 a.b c).

Though the decomposer group collembola were numerically more abundant during cropping in all the experimental plots receiving different treatments, coleoptera larvae contributed significantly to the biomass of soil faunal community structure .Thus the experiment with the different treatments of soil using different FYM affected soil collembola more directly and other arthropod groups respose did not vary significantly between different treatments. But the actual conclusion will be arrived at only after the plant as well as soil analysis will be completed.

OBSERVATIONS

- Land management practices alter soil conditions and the soil community of micro-, meso- and macro-organisms, the <u>structure of soil communities</u> is largely determined by ecosystem characteristics and land use systems.

- Management strategies, such as, crop rotations, use of plant residues and manure, poor vegetation cover and/or lack of plant litter covering change soil habitats and the food web and alter soil quality, which in turn tend to alter the number of soil organisms community structure.
- Earthworms were absent from the degraded ecosystems , however the based on the ecological catagories different species responded differently to level of perturbations.
- Soil vegetation cover determines the composition of soil arthropod community structure with the primary consumers present at the bottom of the food chain being more numerically abundant(Collembola/Acarina).However it was the Secondary consumers(coleoptera as well as coleopteran larvae which have higher biomass at all the sites. Hymenoptera were mostly characteristic of degraded ecosystems.
- Acarina were more abundant in the sites with low moisture content but with well developed vegetation cover.Entomobryomorphids were more abundant on sites with rich litter layer;sminthurids were present in plots with more open spacesor in early successional plots;Podumorphs are dominant in the well developed porous soils with rich organic matter.
- All these observations could actually be confirmed only after the soil as well as plant analysis will be completed.

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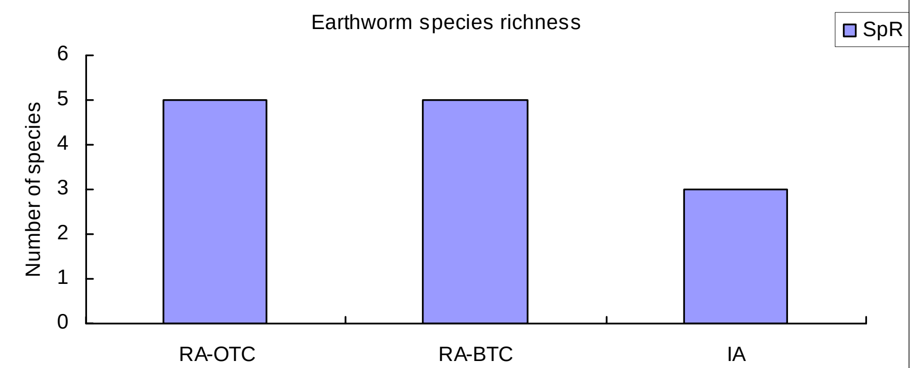

Fig1a.Effect of agriculture management Practices on earthworm species(RA-OTC rainfed agriculture outside tree canopy;RA-BTC rainfed agriculture below tree canopy;IA irrigated agriculture

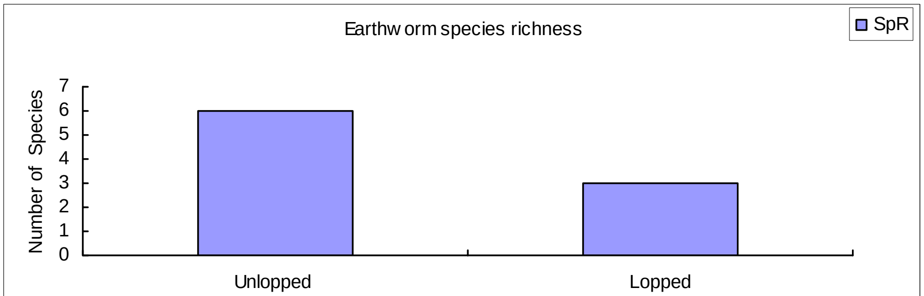

Fig2aEffect of practice of lopping of tree branches on the Earthworms species richness

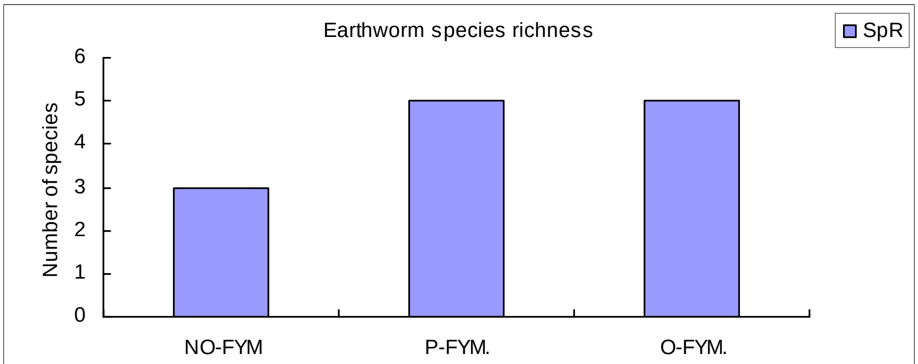

Fig3a Effect of addition of plant residues as Farmyard manure to the soil and subsequently on the earthw ormssp richness.FYM Farmyard manure;P-FYM Pine based farmyard manure;O-FYM Oak based Farmyard manure.

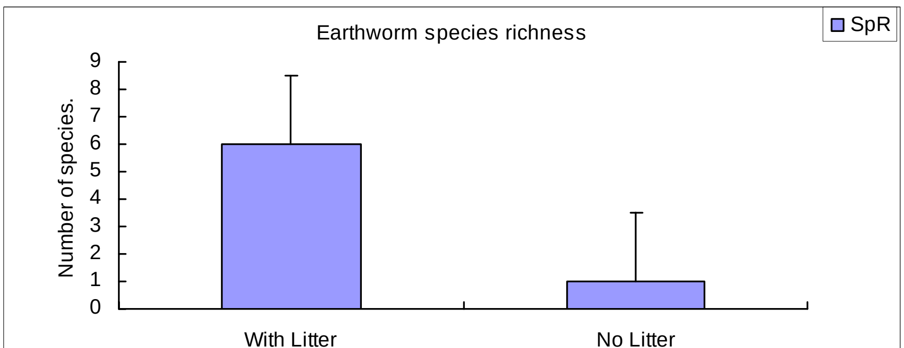

Fig 4a Effect of removal of litter from forest floor on the earthworms species richness

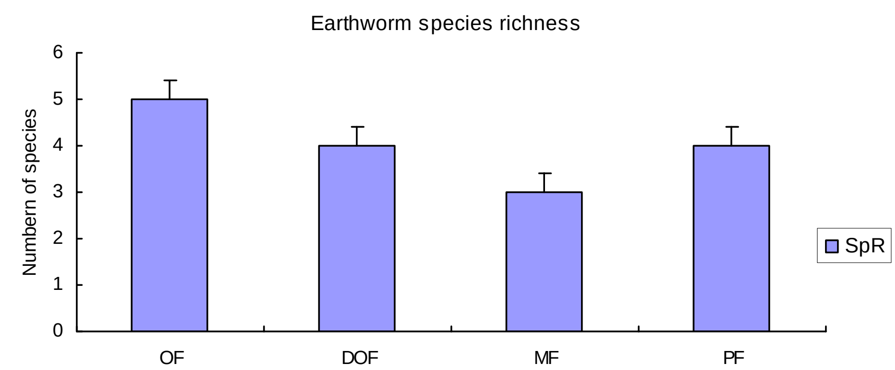

Fig5aEffect of degradation of natural ecosystemson the earthw orms species richness.OF oak forest;DOF Disturbed oak forest; MFMixed forest;PF Pine forest

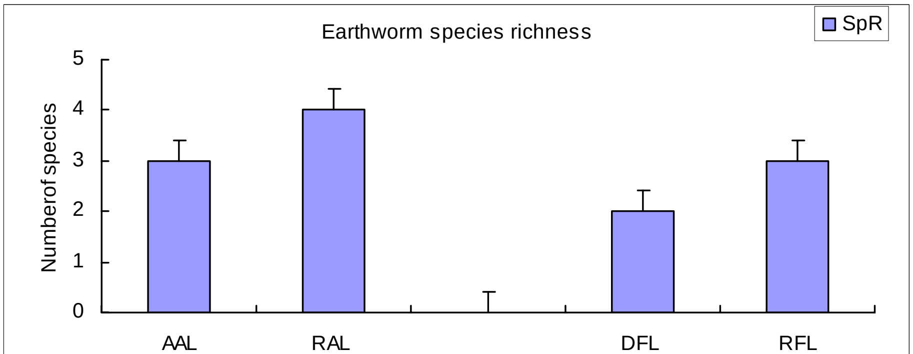

Fig 6a Effect of reclamation of degraded agroecosystems as w ell forest ecosystem on earthw orms species richness.AAL abandonend agriculture land ;RAL Reclaimed agricultural land;DFL Degraded forest land; RFL Reclaimed forest land.

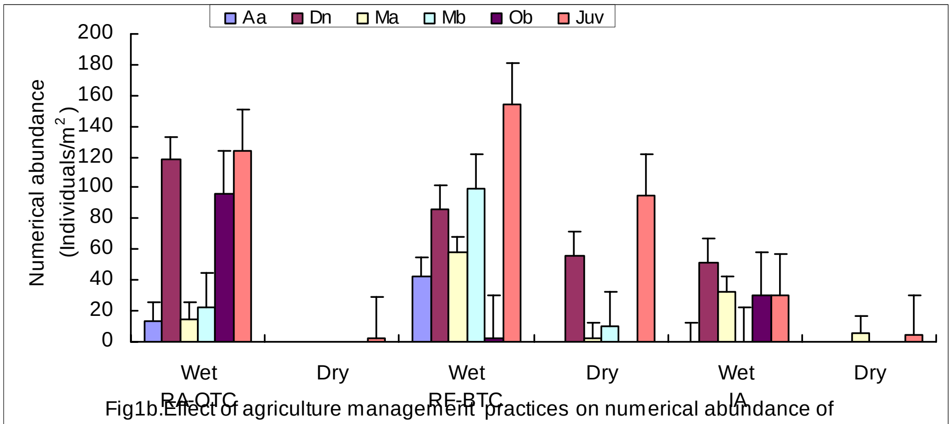

Fig1b.Effect of agriculture management practices on numerical abundance of earthworm species.WET(JUNE-OCT), DRY(Nov-MAY)*(Aa A.alexandri ;Dn D.nepalensis;Ma M.anamola;Mb M.birmanica;Ob O.beatrix ;Juveniles*

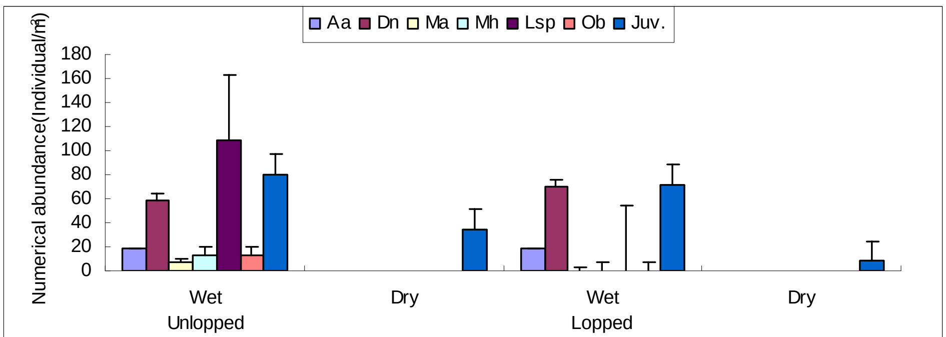

Fig2bEffect of practice of lopping of tree branches on numerical abundance of earthworm species.WET(JUNE-OCT),DRY(Nov-MAY);(Aa *A.alexandrii ;Dn D.nepalensis;Ma M.anamola;M.holutii;Ob O.beatrix* ;Juveniles

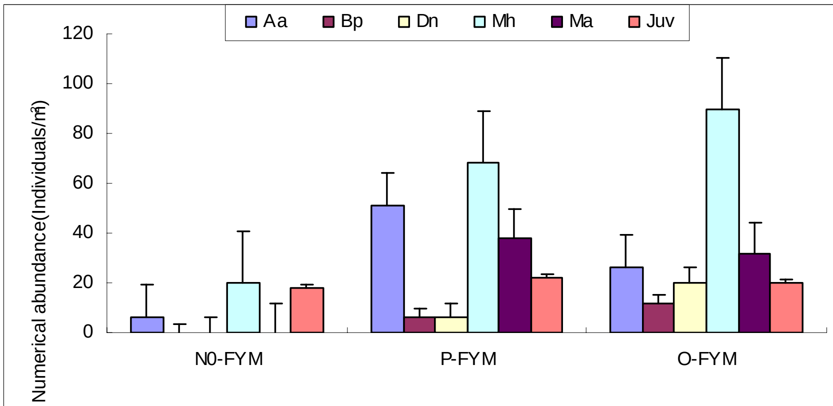

Fig3b Effect of addition of plant residues as Farmyard manure to the soil and subsequentlyon numerical abundance of earthw orm species.;(*Aa A.alexandrii ;Bp B.parvus;Dn D.nepalensis;Ma M.anamola;M.holutii;;Juvenile*

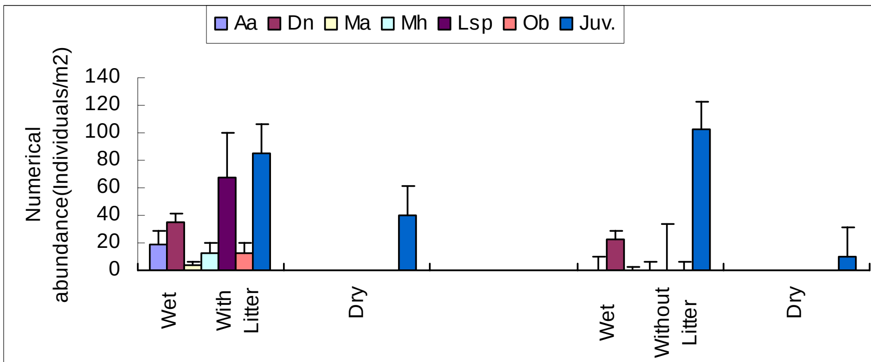

Fig4b Effect of removal of litter from forest floor on on numerical abundance of earthw orm species.;(Aa A.alexandrii ;;Dn D.nepalensis;Ma M.anamola;M.holutii;Lsp Lennogaster species;Juvenile

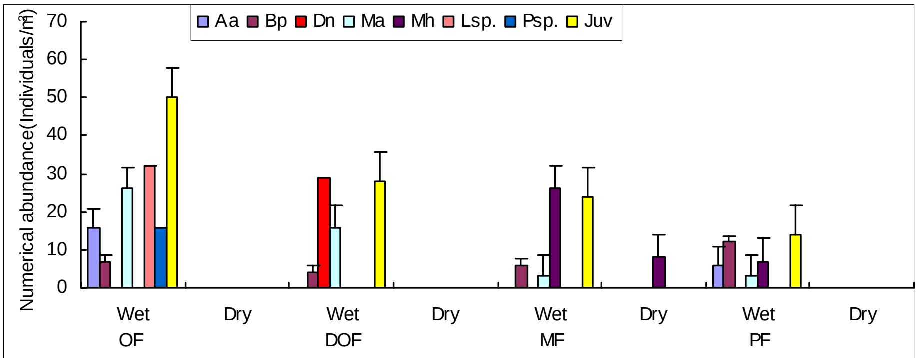

Fig5b Effect of degradation of natural ecosystem on numerical abundance of earthworm species.*Aa A.alexandrii;Bp B.parvus;D.nepalensis;M.anamola;Mh M holutii;Lennogaster sp.;Psp Perionyx sp.*

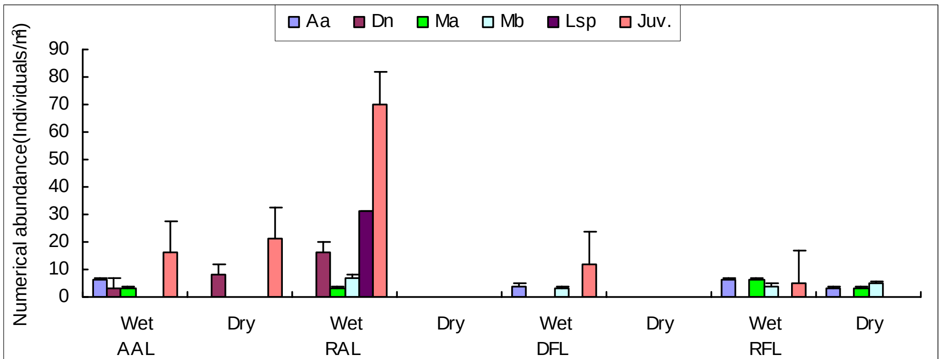

Fig 6b Effect of reclamation of degraded agroecosystems as well forest ecosystem on numerical abundance of earthworm species.*Aa .alexandrii;;D.nepalensis;M.anamola;Mh M birmanicaii;Lennogaster sp.;Juveniles*

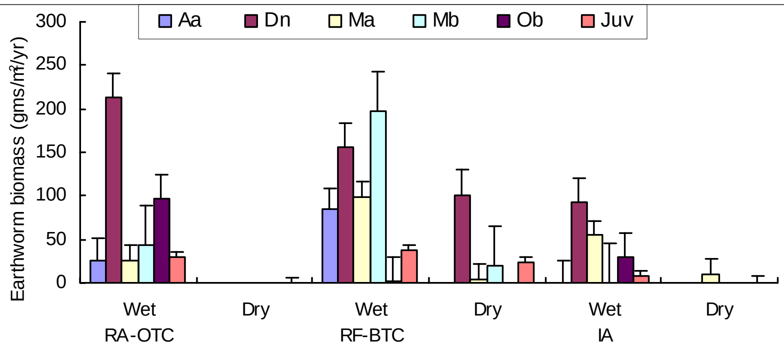

Fig1c.Effect of agriculture management practices on biomass of earthworm species.WET(JUNE-OCT),DRY(Nov-MAY)((*Aa A.alexandri ;Dn D.nepalensis;Ma M.anamola;Mb M.birmanica;Ob O.beatrix ;Juveniles* s)

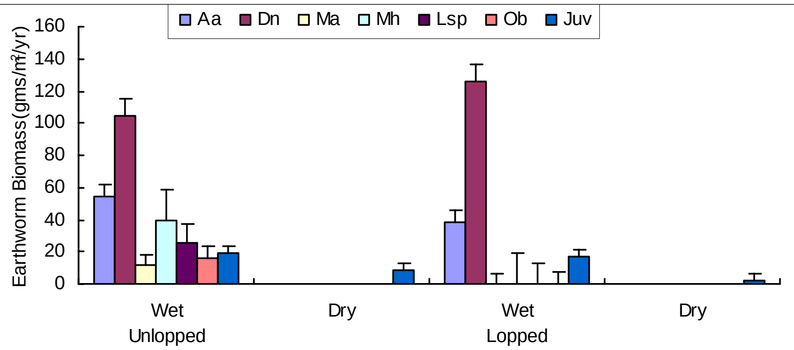

Fig2c Effect of practice of lopping of tree branches on biomass of earthworm species(*Aa A.alexandri ;Dn D.nepalensis;Ma M.anamola;Mholutii; M.birmanica;Ob O.beatrix ;Juveniles)*

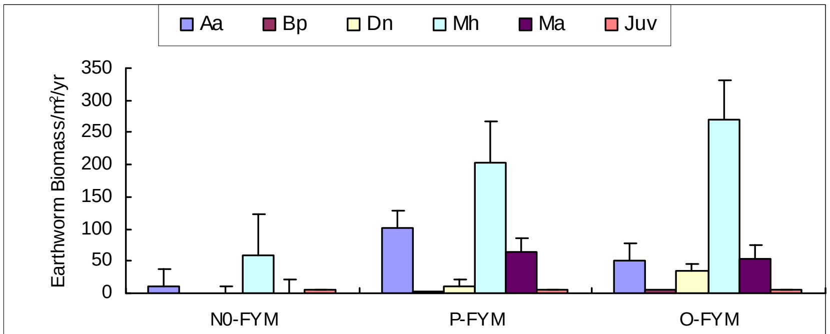

Fig3c Effect of addition of plant residues as Farmyard manure to the soil and subsequently on biomass of earthw orm speciess.;(*Aa A.alexandrii ;Bp B.parvus;Dn D.nepalensis;Ma M.anamola;M.holutii;;Juvenile)*

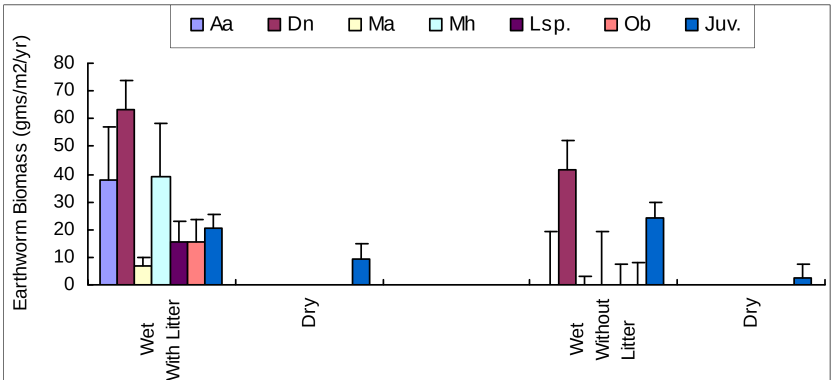

Fig4c Effect of removal of litter from forest floor on biomass of earthw orm species .;(*Aa A.alexandrii ;;Dn D.nepalensis;Ma M.anamola;M.holutii;Lsp Lennogaster species* ;Juvenile

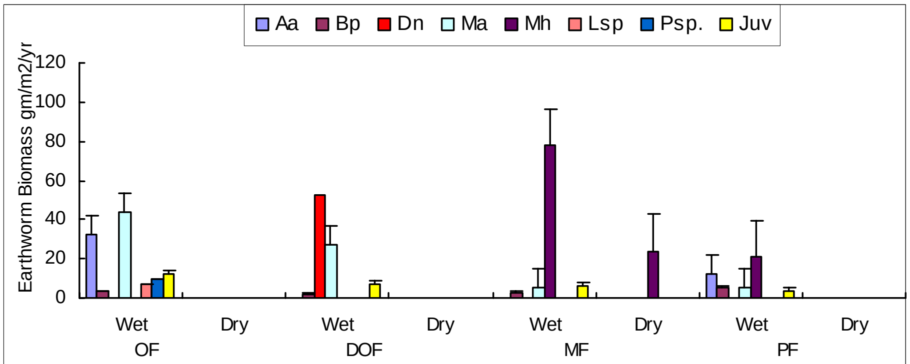

Fig5c Effect of degradation of natural ecosystem on biomass of earthw orm species.*Aa A.alexandrii;Bp B.parvus;D.nepalensis;M.anamola;Mh M holutii;Lennogaster sp.;Psp Perionyx sp.*

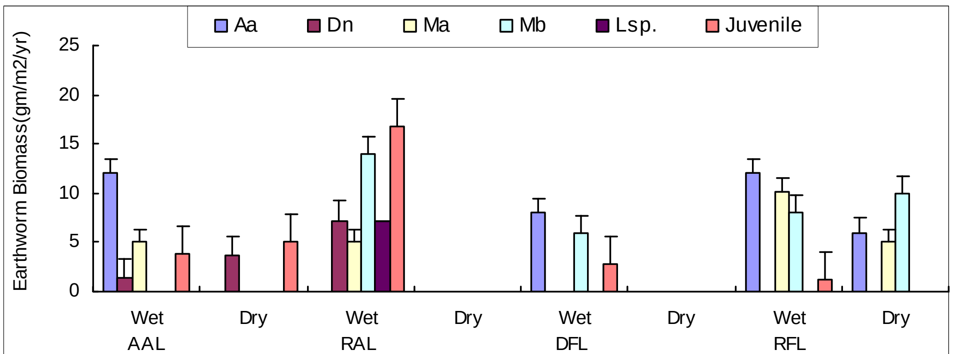

Fig6c Effect of reclamation of degraded agroecosystems as well forest ecosystem on biomass of earthworm species.Aa A.alexandrii D.nepalensisis;M.anamola;Mb M birmanicai;Lennogaster sp.;Juveniles.

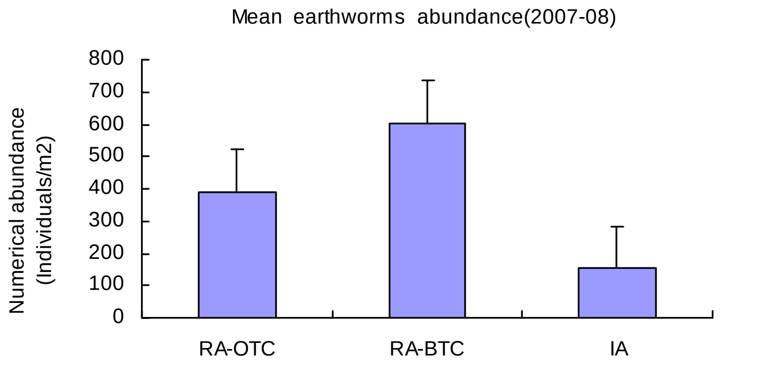

Fig1d.Effect of agriculture management practices on mean abundance of earthworm species.

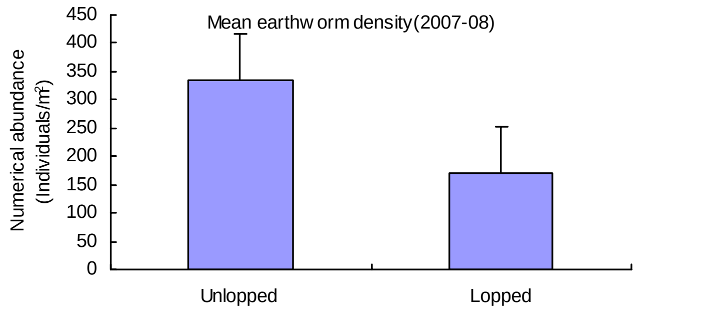

Fig2d Effect of practice of lopping of tree branches on mean numerical abundance of earthworm species

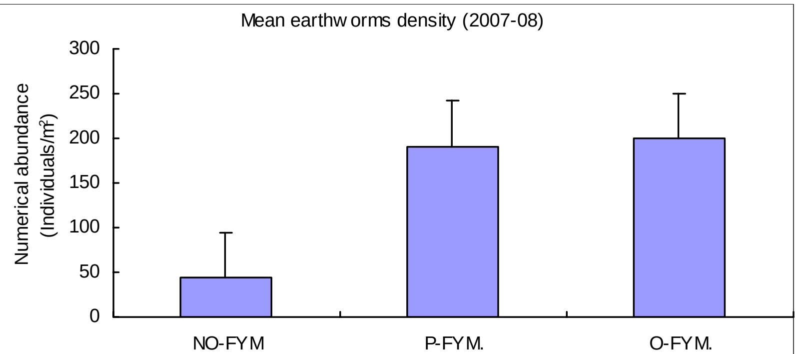

Fig3d Effect of addition of plant residues as Farmyard manure to the soil and subsequently on mean numerical abundance of earthworm species

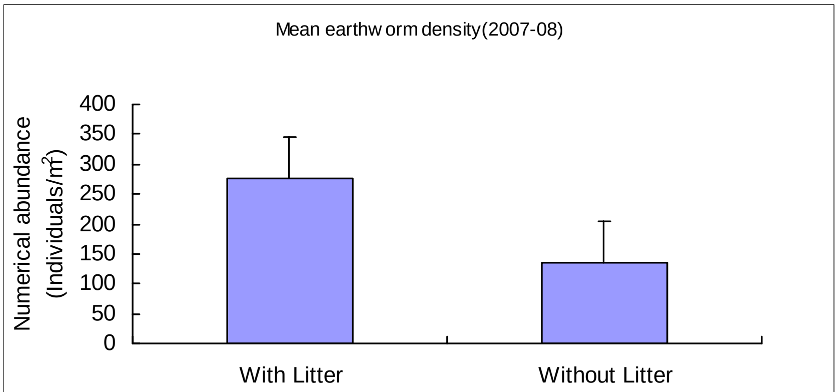

Fig4d Effect of removal of litter from forest floor on mean numerical abundance of earthw orm species .

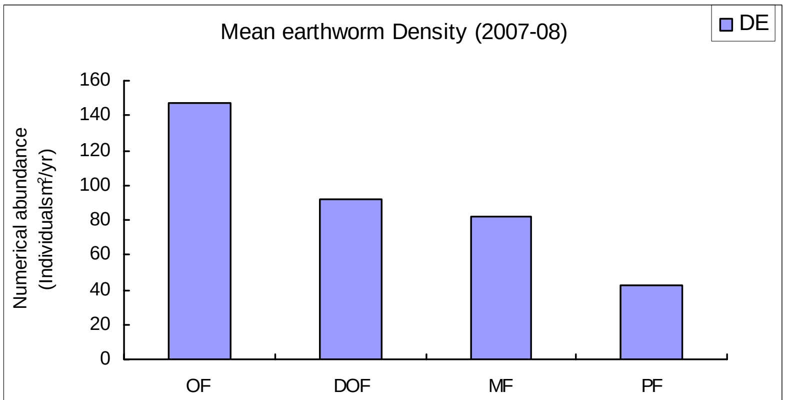

Fig5d Effect of degradation of natural ecosystem on mean numerical abundance of earthw orm species.

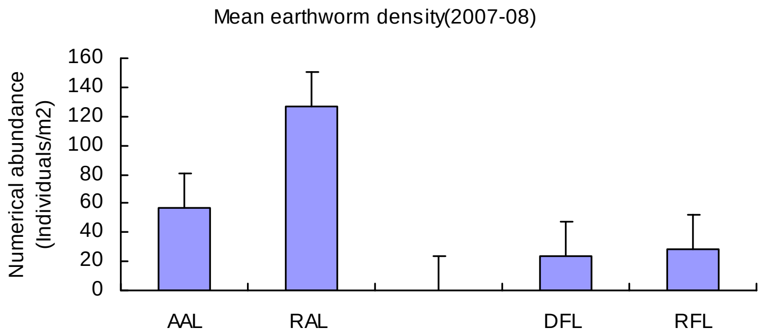

Fig6d Effect of reclamation of degraded agroecosystems as well forest ecosystem on mean numerical abundance of earthworm species.

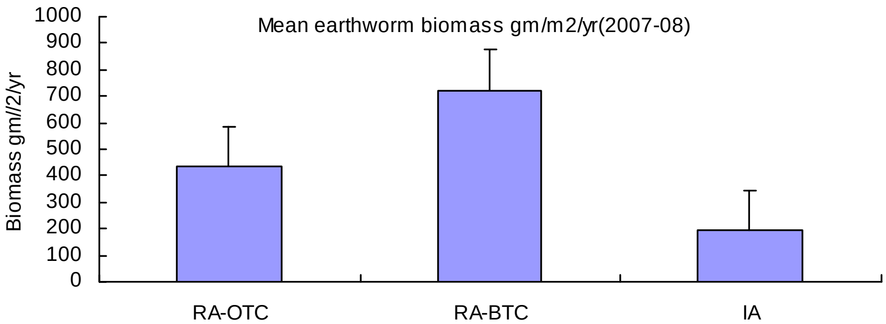

Fig1e.Effect of agriculture management practices on biomass gm/m2 of earthworm species.

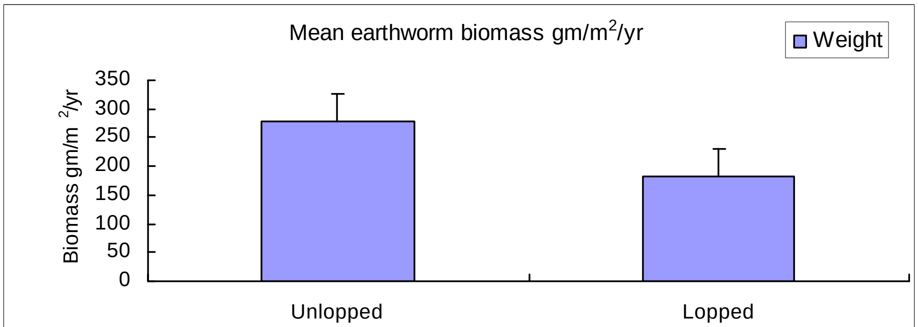

Fig2e Effect of .practice of lopping of tree branchess on biomass gm/m^2 of earthworm species

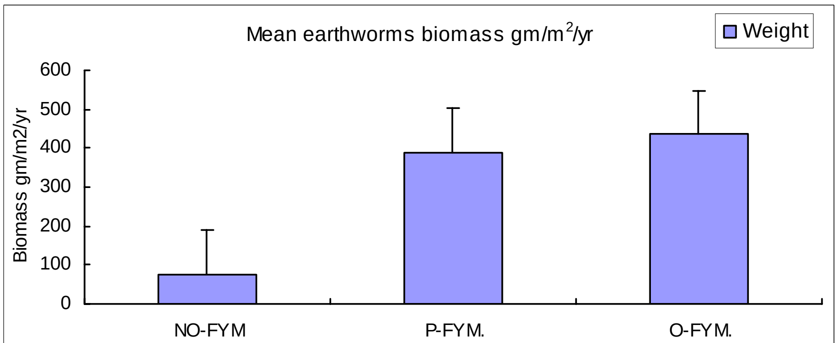

Fig3e Effect of addition of plant residues as Farmyard manure to the soil and subsequently on biomass gm/m2 of earthworm species

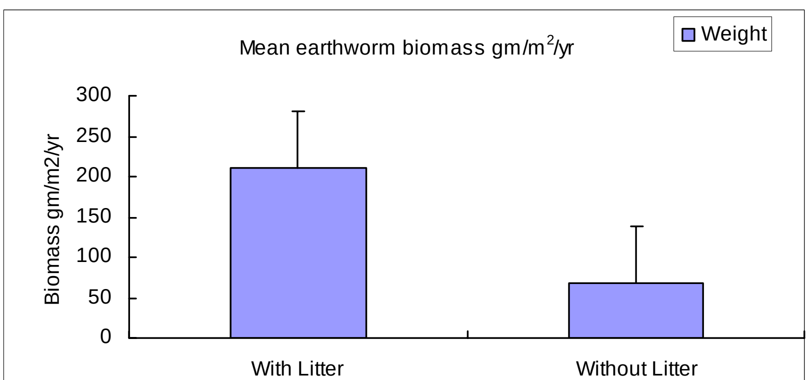

Fig4e Effect of removal of litter from forest floor on biomass gm/m^2 of earthworm species .

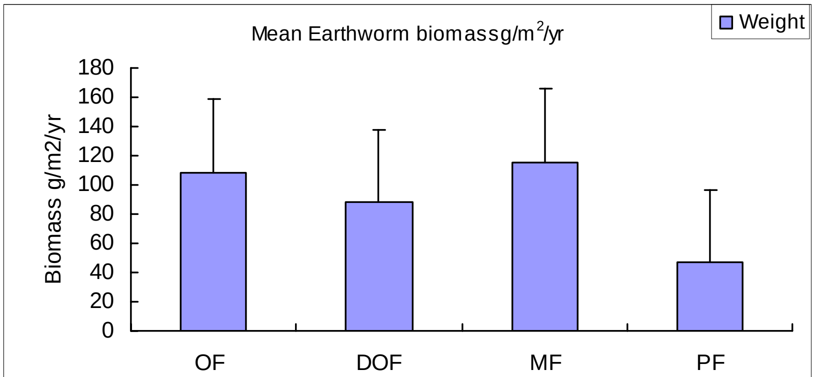

Fig5e Effect of degradation of natural ecosystem on biomassgm/m^{2}of earthw orm species.

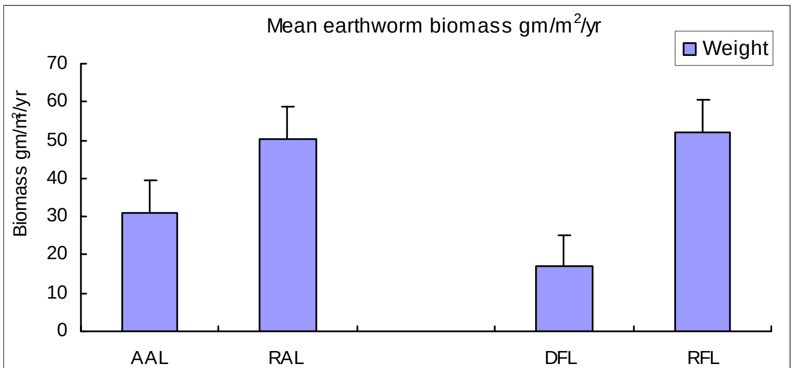

Fig6eEffect of reclamation of degraded agroecosystems as w ell forest ecosystem on biomass gm/m^{2}of earthw orm species.

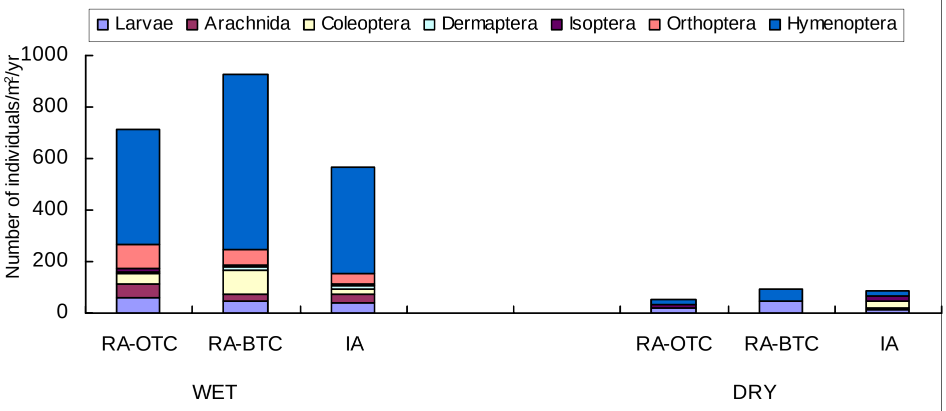

Fig7a.Effect of agriculture management Practices on Soil arthropod(RA-OTC rainfed agriculture outside tree canopy;RA-BTC rainfed agriculture below tree canopy;IA irrigated agriculture (Hand sorting method**)**

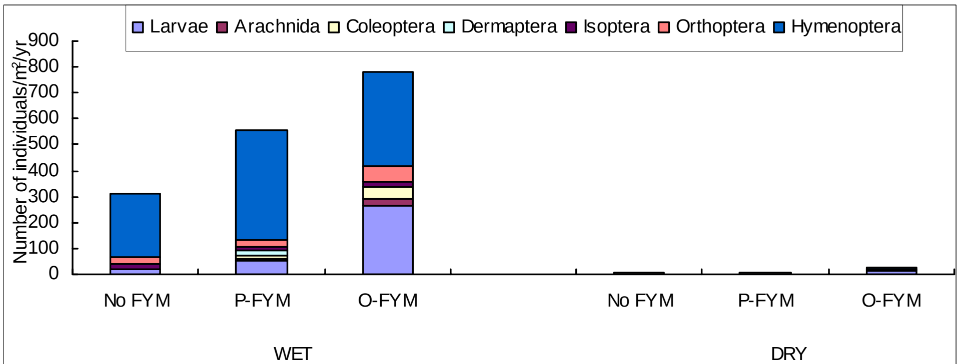

Fig8ab Effect of addition of plant residues as Farmyard manure to the soil and subsequently on numerical abundance of soil arthropods (hand sorting methods)FYM Farmyard manure;P-FYM Pine based farmyard manure;O-FYM Oak based Farmyard manure.

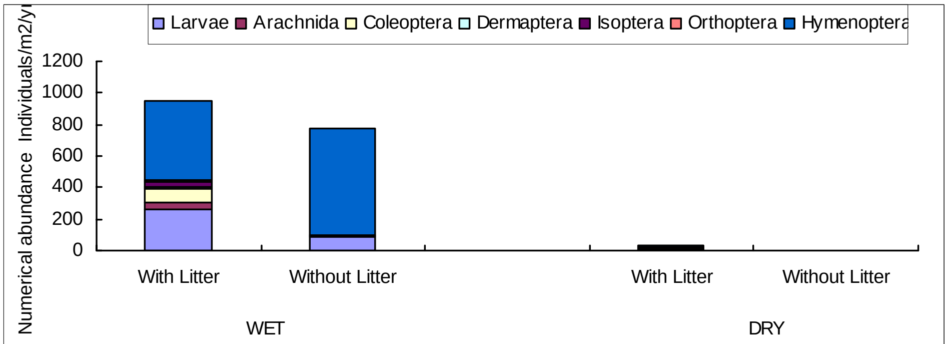

Fig9a Effect of removal of litter from forest floor on on numerical abundance of soil arthro[ods (Hand sorting methods).

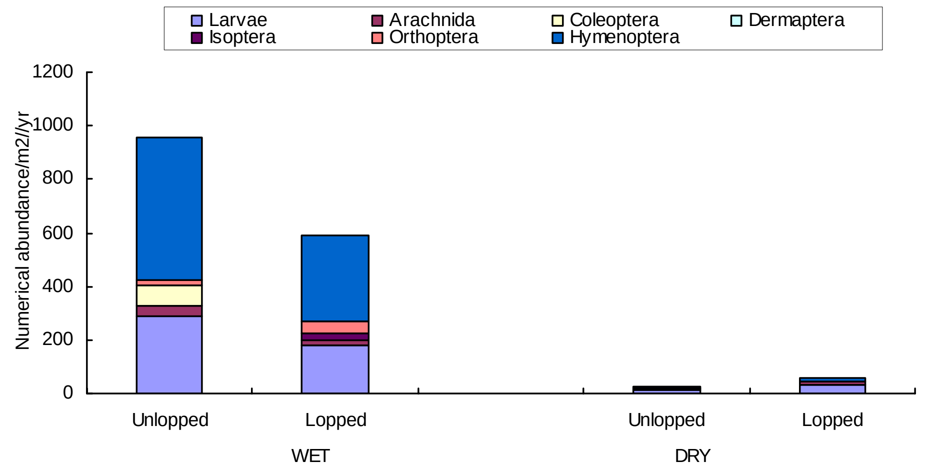

Fig10a Effect of practice of lopping of tree branches on numerical abundance of soil arthropods(Hand sorting methods.WET(JUNE-OCT),DRY(Nov-MAY)

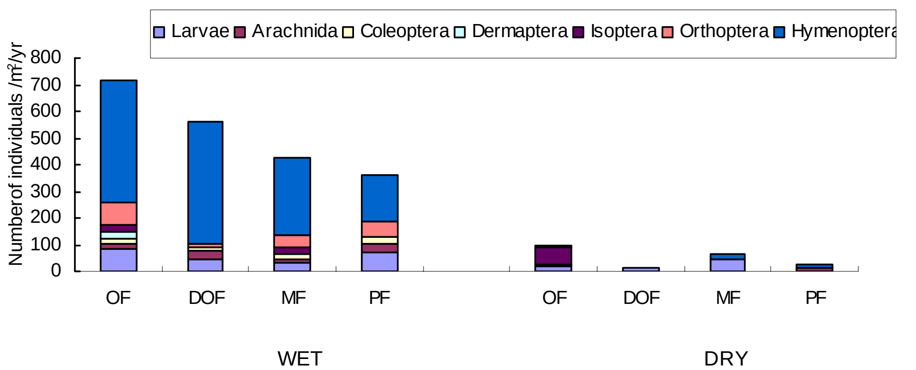

Fig11a Effect of degradation of natural ecosystem on numerical abundance of soil arthropods(Hand sorting methods)OF oak forest;DOF Disturbed oak forest; MFMixed forest;PF Pine forest..

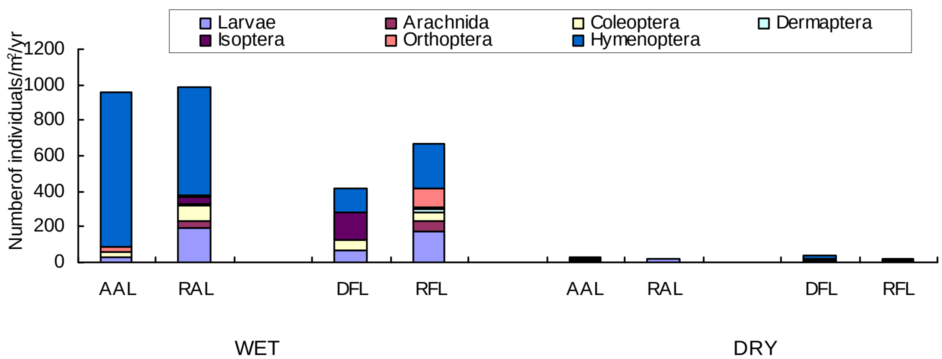

Fig 12a Effect of reclamation of degraded agroecosystems as w ell forest ecosystem on numerical abundance of soil arthropods(Hand sorting methods).AAL abandoned agriculture land ;RAL Reclaimed agricultural land;DFL Degraded forest land; RFL Reclaimed forest land..

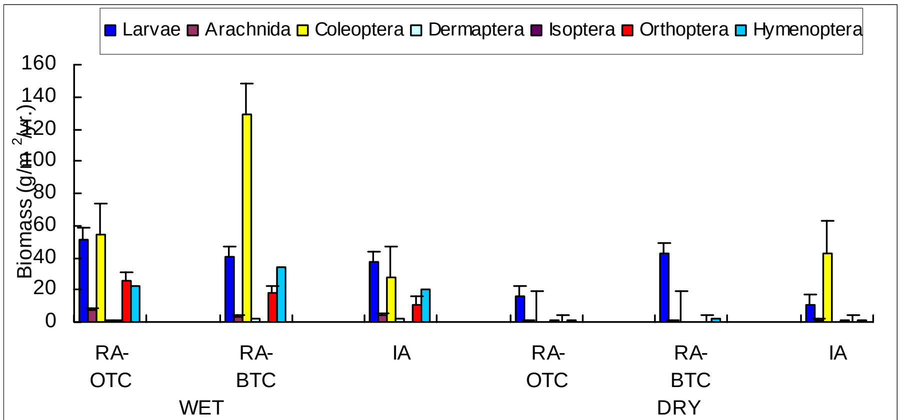

Fig7b.Effect of agriculture management Practices on Mean soil arthropod Biomass(gm/m2/yr).WET(JUNE-OCT);DRY(Nov-MAY)

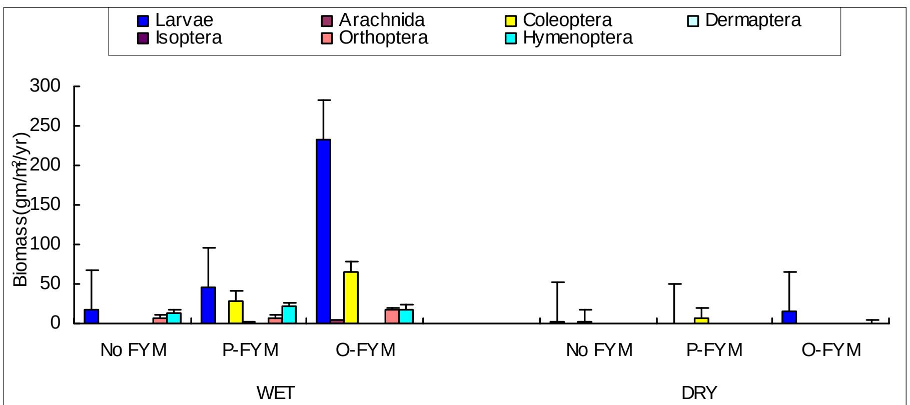

Fig8b Effect of addition of plant residues as Farmyard manure to the soil and subsequently on Mean soil arthropod Biomass(hand sorting methods)

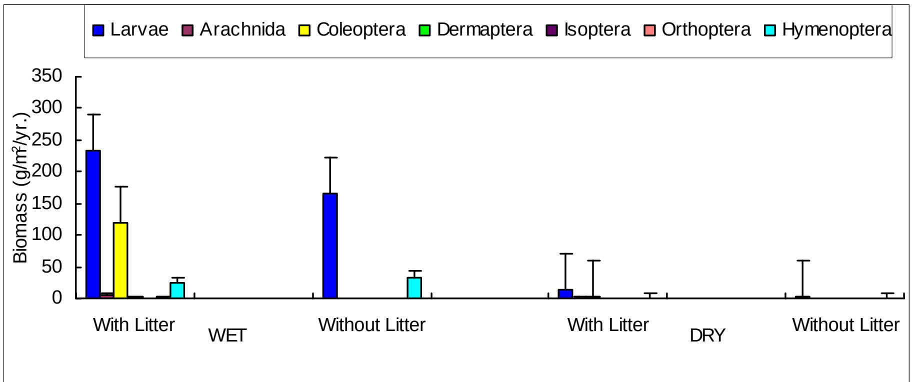

Fig9b Effect of removal of litter from forest floor on Mean Arthropod Biomass(gm/m2/yr (Hand sorting methods).

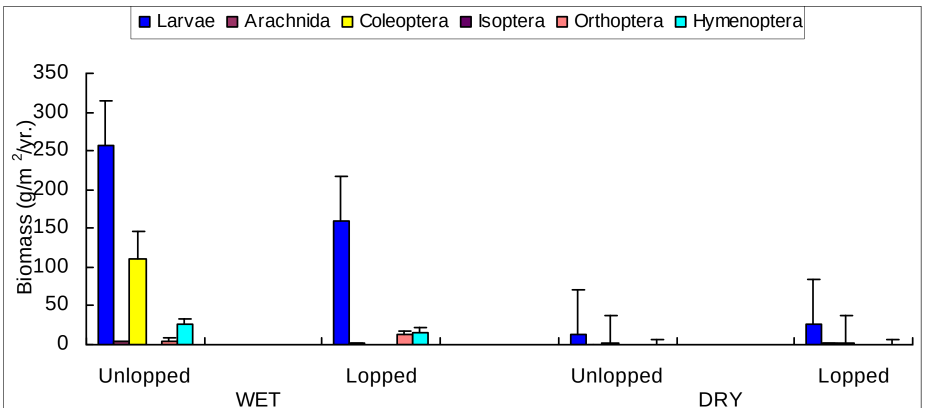

Fig10b Effect of practice of lopping of tree branches on Mean Arthropod Biomass(gm/m2/yr)(Hand sorting methods).

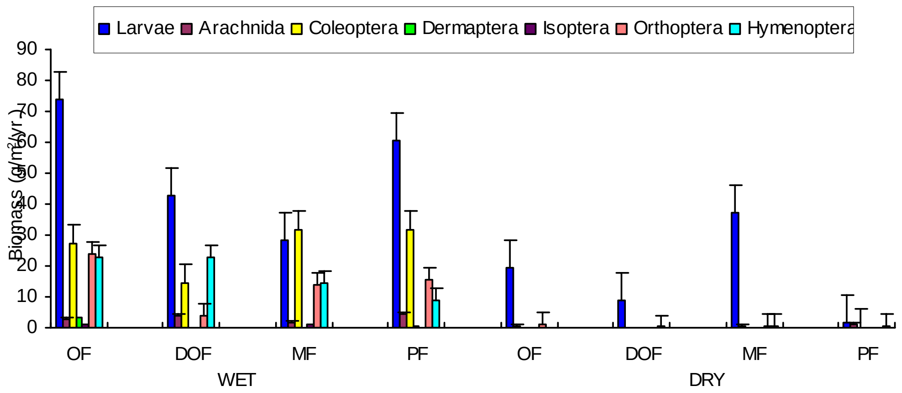

Fig11b Effect of degradation of natural ecosystem on Mean Arthropod Biomass(gm/m2/yr)(Hand sorting methods).

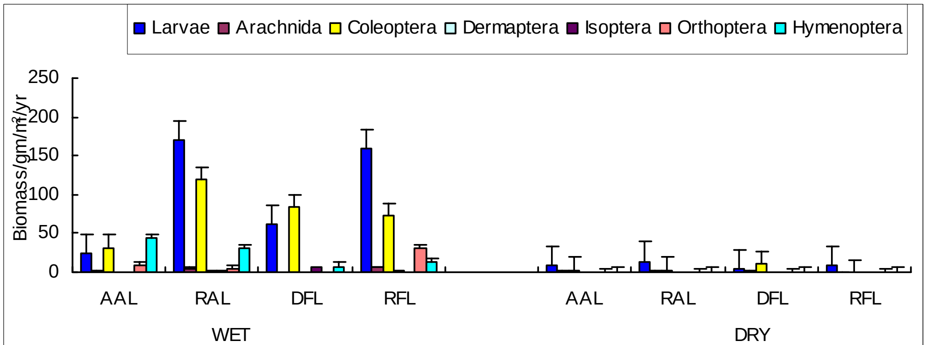

Fig 12b Effect of reclamation of degraded agroecosystems as w ell forest ecosystem on Mean Arthropod Biomass(gm/m2/yr)(Hand sorting methods)..

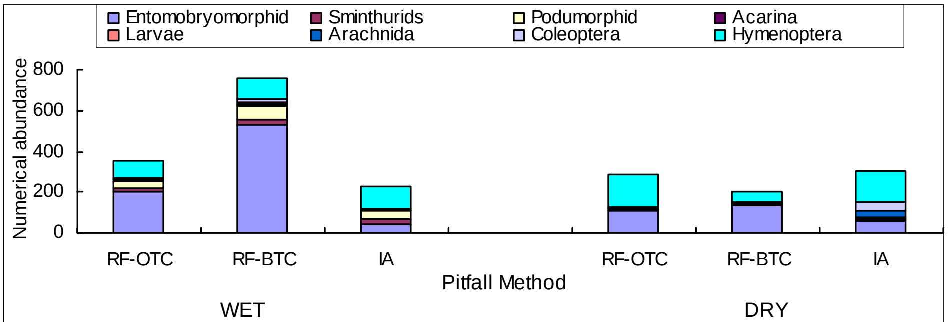

Fig13a.Effect of agriculture management Practices on Soil arthropod(Pitfall Method)(RA-OTC rainfed agriculture outside tree canopy;RA-BTC rainfed agriculture below tree canopy;IA irrigated agriculture ..WET(JUNE-OCT),DRY(Nov-MAY)

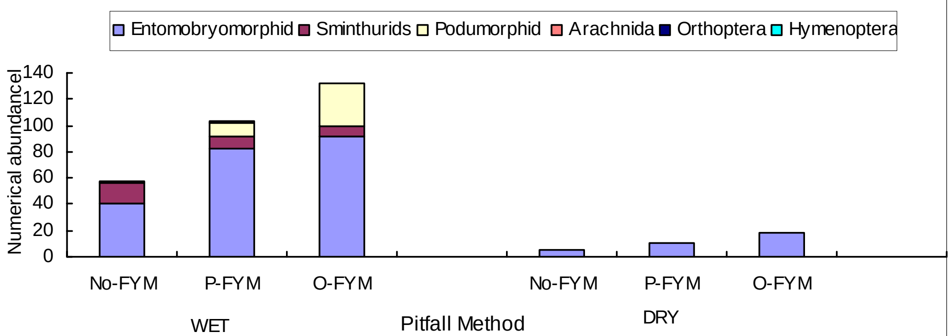

Fig14a Effect of addition of plant residues as Farmyard manure to the soil and subsequently on numerical abundance of soil arthropods FYM Farmyard manure;P-FYM Pine based farmyard manure;O-FYM Oak based Farmyard manure.

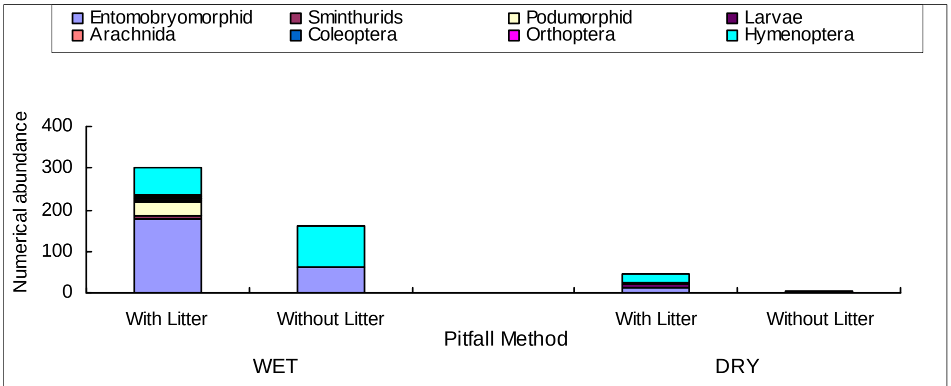

Fig15a Effect of removal of litter from forest floor on on numerical abundance of soil arthropods (Pitfall Methods)

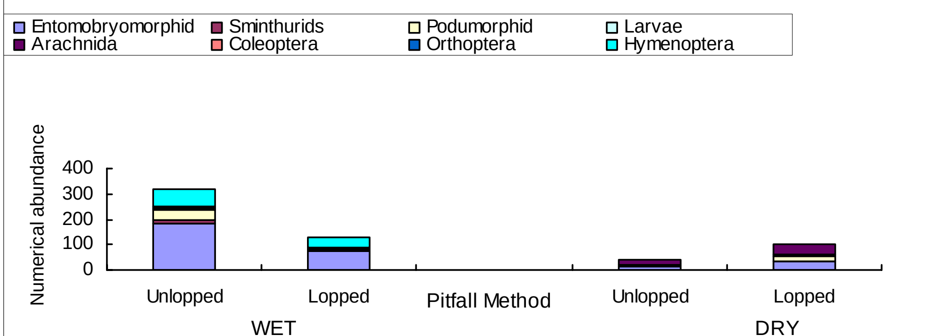

Fig16a Effect of practice of lopping of tree branches on numerical abundance of soil arthropods(Pitfall Method)

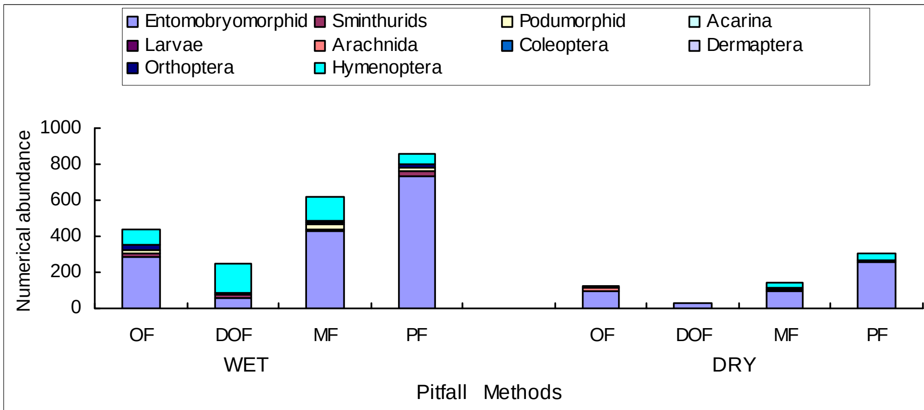

Fig17a Effect of degradation of natural ecosystem on numerical abundance of soil arthropods(Pitfall methods)OF oak forest;DOF Disturbed oak forest; MFMixed forest;PF Pine forest..

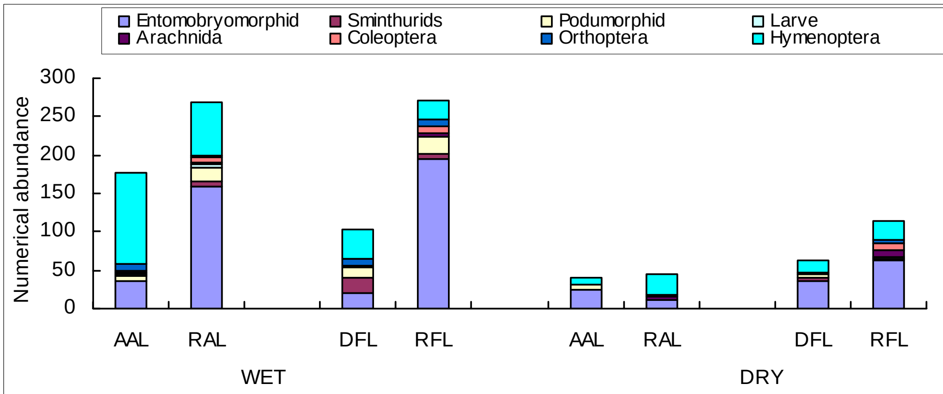

Fig 18a Effect of reclamation of degraded agroecosystems as w ell forest ecosystem on numerical abundance of soil arthropods(Pitfall Method).AAL abandoned agriculture land ;RAL Reclaimed agricultural land;DFL Degraded forest land; RFL Reclaimed forest land..

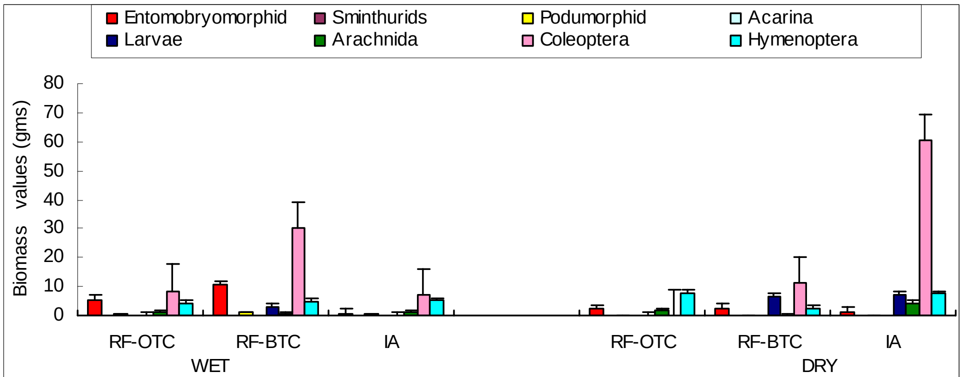

Fig13b.Effect of agriculture management Practices on Mean arthropod biomass(Pitfall method).

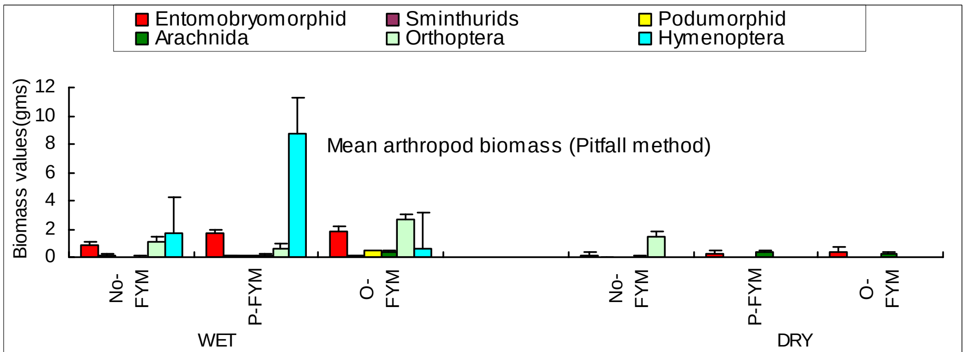

Fig14b Effect of addition of plant residues as Farmyard manure to the soil and subsequently Mean arthropod biomass (Pitfall method)

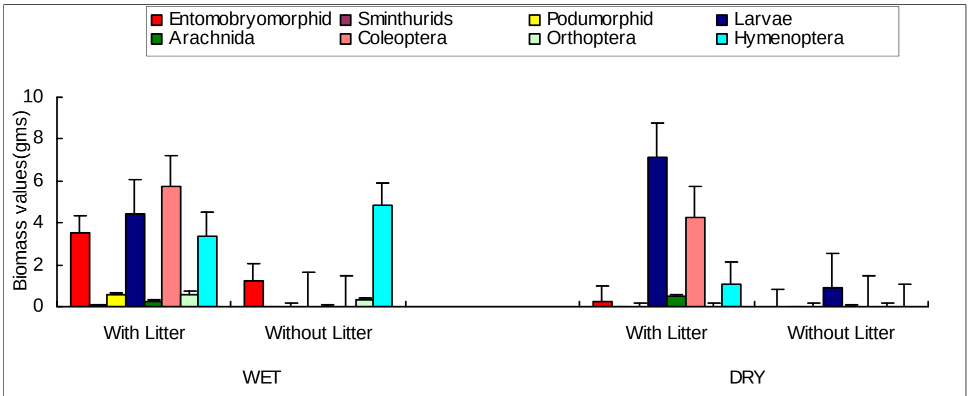

Fig15b Effect of removal of litter from forest floor on Mean arthropod biomass (Pitfall method)

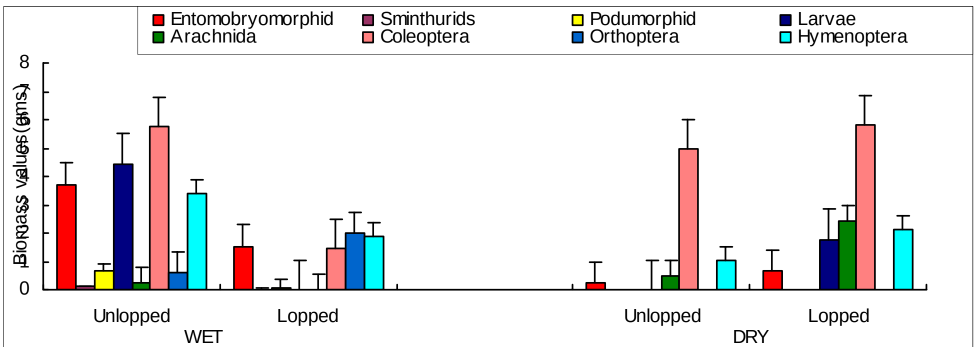

Fig16b Effect of practice of lopping of tree branches on Mean arthropod biomass(Pitfall method)

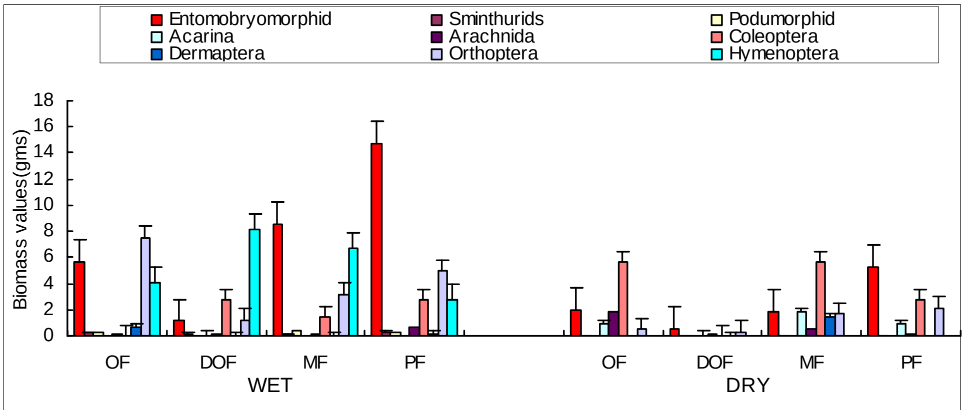

Fig17b Effect of degradation of natural ecosystem on Mean arthropod biomass(Pitfall)

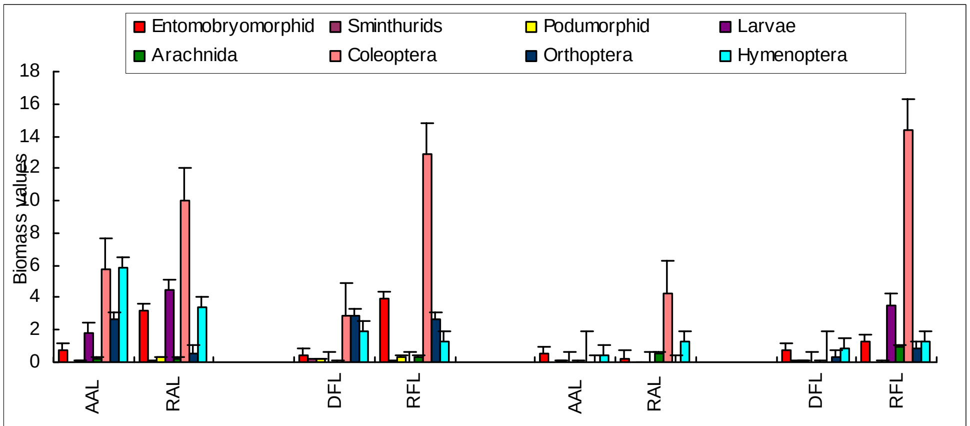

Fig 18b Effect of reclamation of degraded agroecosystems as well forest ecosystem on Mean arthropod biomass(Pitfall method).

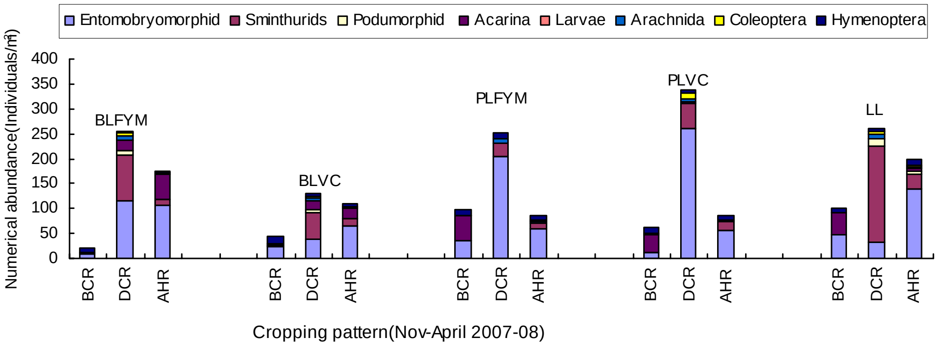

Fig25a Effect of use of different types of Farm Yard manures in experimental plots on the numerical abundance of soil arthropods (Pitfall method) in pea crops.BLFYM Broad leaf farm yard manure;BLVC Broad leafbased Vermicompost;PLFYM Pine litterbased farm yard manure;PLVCPine leafbased Vermicompost;LLfresh forest litter.

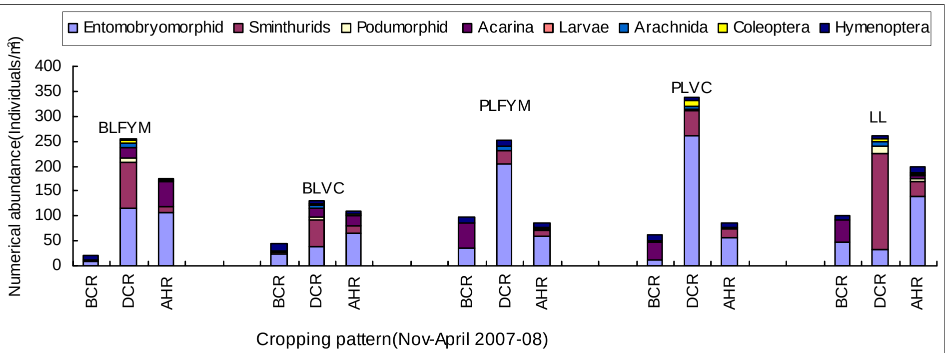

Fig25a Effect of use of different types of Farm Yard manures in experimental plots on the numerical abundance of soil arthropods (Pitfall method) in pea crops.BLFYM Broad leaf farm yard manure;BLVC Broad leafbased Vermicompost;PLFYM Pine litterbased farm yard manure;PLVCPine leafbased Vermicompost;LLfresh forest litter.

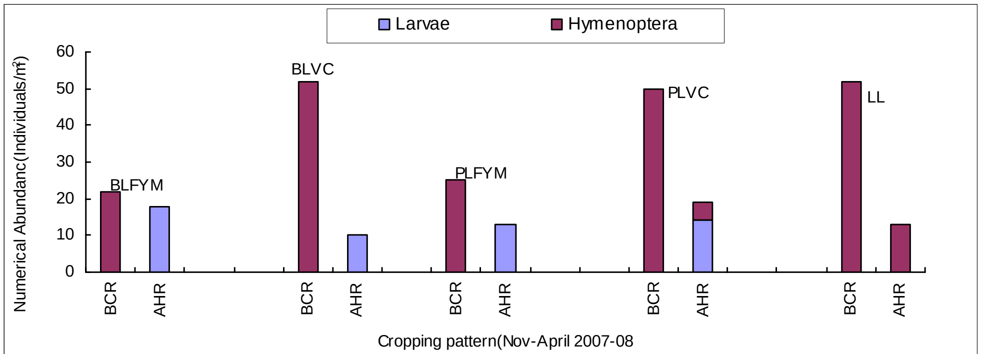

Fig27a Effect of use of different types of Farm Yard manures in experimental plots on Mean numerical abundabnce for soil arthropods(gm/m2/yr) in pea crops.(Hand sorting Method)

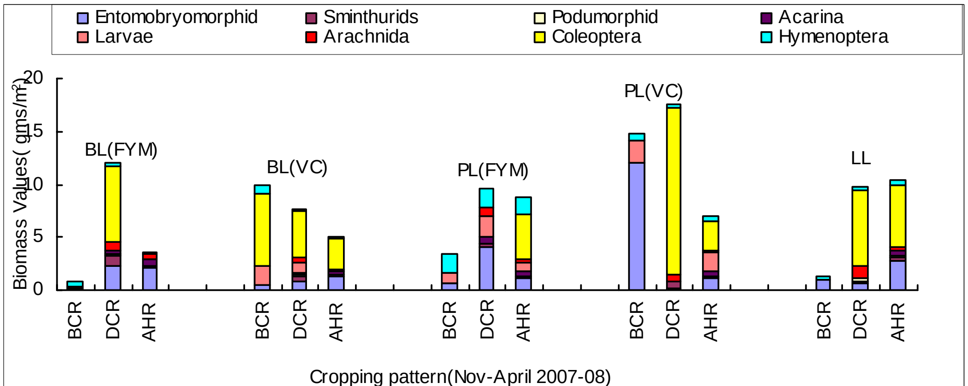

Fig25B Effect of use of different types of Farm Yard manures in experimental plots on Mean biomass of soil arthropods (Pitfall method) in pea crops. BCR before cropping ;DCR During cropping;AHR after the harvest

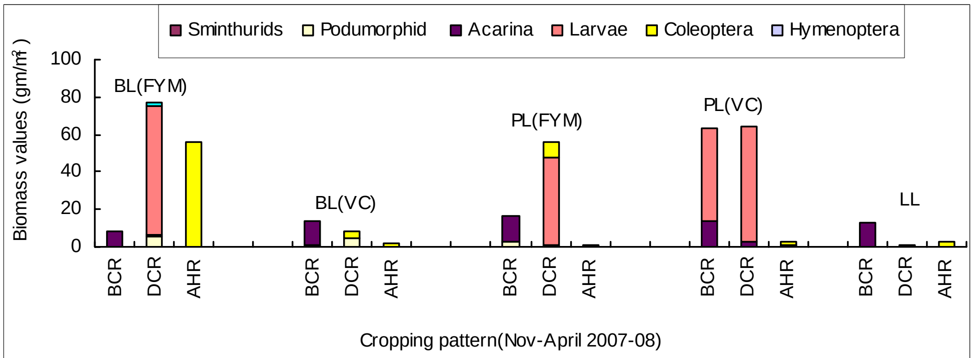

Fig26b Effect of use of different types of Farm Yard manures in experimental Pea plots on Mean biomass values for soil arthropods(gm/m2) in pea crops using Berlese funnel method.

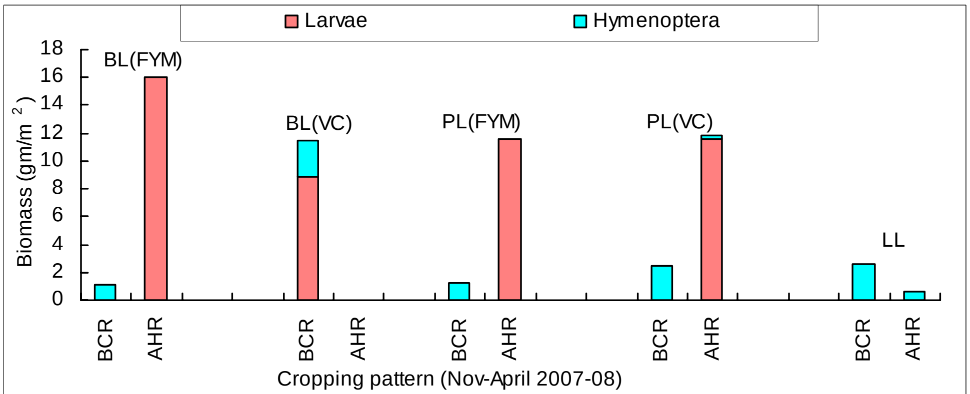

Fig27b Effect of use of different types of Farm Yard manures in experimental plots on Mean biomass values for soil arthropods (gm/m2)using hand sorting method.BCR Before cropping;AHR After harvesting.

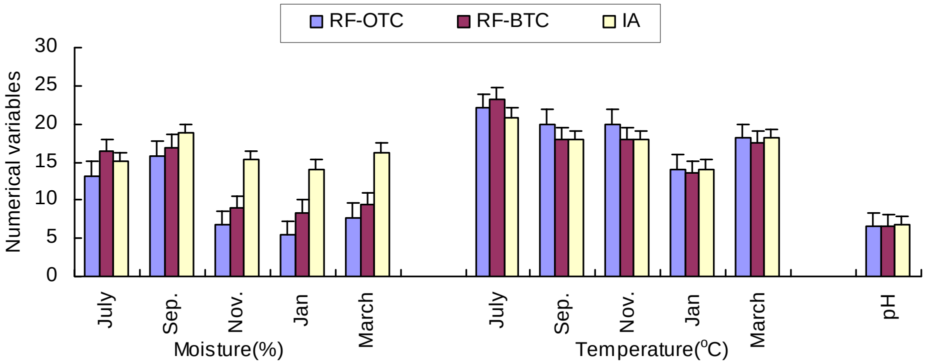

Fig2A.Fluctuation in Soil moisture , Temperature as well as pH distribution under different agriculture management Practices RA-OTC rainfed agriculture outside tree canopy;RA-BTC rainfed agriculture below tree canopy;IA irrigated agriculture .

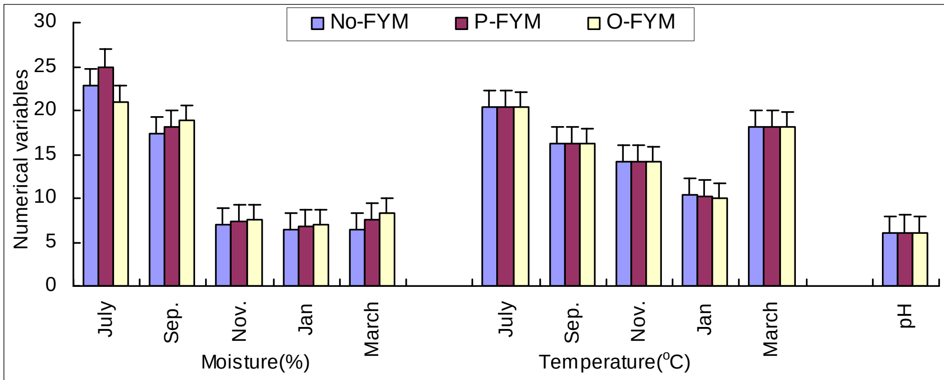

Fig2MB.Fluctuation in Soil moisture , Temperature as well as pH distribution under different addition of plant residues additions as Farmyard manure to the soil FYM Farmyard manure;P-FYM Pine based farmyard manure;O-FYM Oak based Farmyard manure.

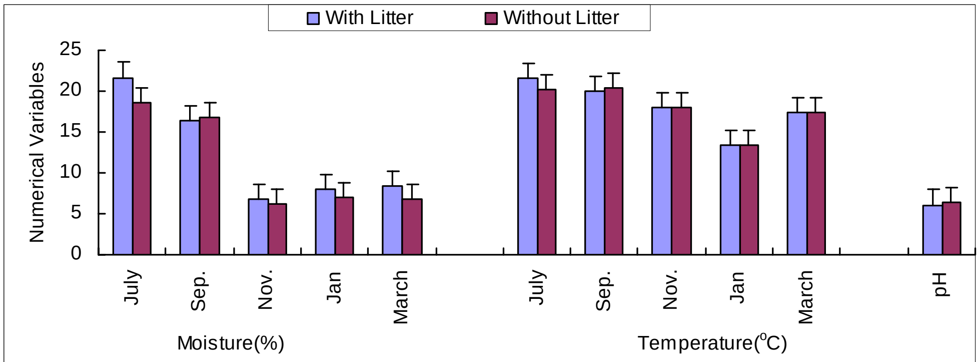

Fig2C.Fluctuation in Soil moisture , Temperature as well as pH distribution under plots With removal of litter from forest floor as well as Without removal of Litter from forest floor.

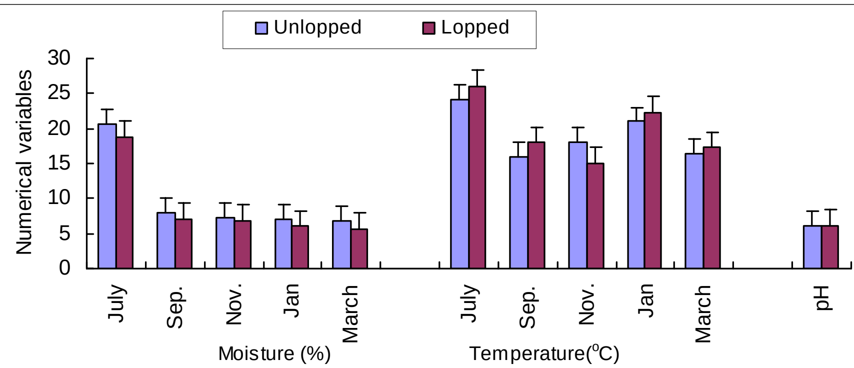

Fig2D Effect of practice of lopping of tree branches on fluctuation in Soil moisture , Temperature as well as pH distribution .

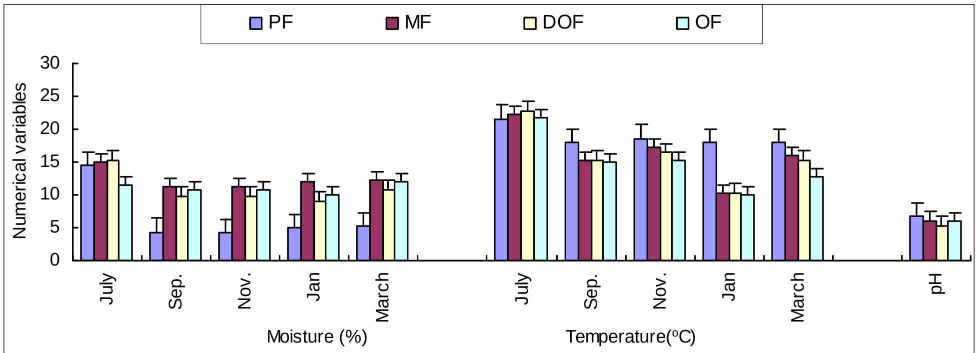

Fig2E Effect of degradation of natural ecosystem on fluctuation in Soil moisture , Temperature as well as pH distribution .

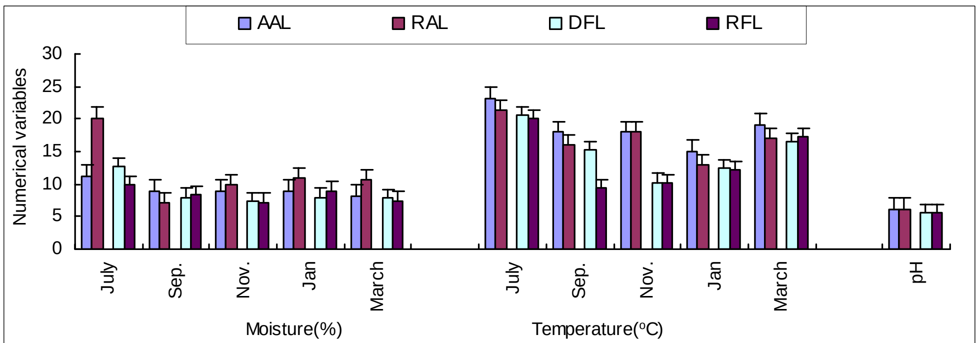

Fig2F Effect of reclamation of degraded agroecosystems as w ell forest ecosystem fluctuation in Soil moisture , Temperature as w ell as pH distribution ..AAL abandoned agriculture land ;RAL Reclaimed agricultural land;DFL Degraded forest land; RFL Reclaimed forest land..