ABSTRACT
Kumaon Himalaya is one of the unique system rich, in indigenous knowledge and culturally strong. Inspite of constant effort by Government organizations like Indian Council of Agricultural Research Institutes (ICAR) and Ministry of Environment and Forest Institutes, traditional cultivation patterns have not improved particularly in the 1000 - 2000 m elevation range. This made necessary to make our efforts to understand the agroecosystems in different ecological settings.

The linkages between the forest, household and agricultural activities are built up on empirical knowledge transmitted from one generation to the other. Most of the energy requirements are met from the forest for the subsistence livelihood of the local community. Certain tree species *Pinus sp. Quercus spp.*, are intensively used from the forest for nutrient, energy and economic balance of the different subsystems of the village. The dominance of these two species in the forest plays a vital role in agroecosystems characteristics and village ecosystem structure and function. Therefore, the zones dominated by these two species were identified as two major regimes that is Oak and Pine regime in the present thesis to study and compare the villages ecosystem and different subsystems constituting the village ecosystem.

On the hill slopes of Kumaon three major groups of agroforestry systems are evident. These are, agri-silviculture, agro-horticulture and homegardens based on structure and composition of species.
Home gardens: -

Home garden is always perceived as a production unit, but it is also a traditional research field where the empirical knowledge is developed through the interaction with the natural systems (Forest) tested and preserved for the future generations. These are vertically stratified communities with high density of trees, basal area and annual food crops. The management of vertically stratified woody species reflects the richness of the empirical knowledge of these societies with increasing density from top to bottom and increase canopy cover to use the natural light efficiently.

The home gardens of pine regime are dominated by naturally regenerated fuel wood and fodder trees. The surrounding forests are not able to provide fuel and fodder requirements due to restricted accessibility of forests, reduced forest area and smaller land holding size. Home gardens in the Oak regime have high concentration of fruit trees as the fodder and fuel wood requirements are met from the forest as well as crop fields due to accessibility to forests rich in these resources and larger land holdings. However the home gardens showed tendencies to increase fruit trees in both regimes, due to the technological impact from the plains.

Agri-silviculture: -

The agri-silviculture systems are developed from the in situ seed bank by selective protection of naturally regeneration. On the whole six dominant agri-silviculture systems were identified in the traditional societies of Kumaon, five of them (Pyrus pashia, Celtis
_australis, Sapium sabiferum, Grewia oppositifolia and Pinus roxburghii._) are represented in Pine regime and only one (_Quercus leucotrichophora_) is represented in Oak regime.

Among dominant species of the agri-silviculture systems _Pinus roxburghii_ showed narrow range of distribution and the systems indicated its gradual elimination from the agro-ecosystems. Even though _Grewia oppositifolia_, rated high for its fodder, systems are also in narrow range of distribution due to excessive lopping. The _Celtis australis_ is also distributed in the smaller smaller pockets with high land holding villages. However, _Pyrus pashia_ dominated systems are wide spread in all zones with expanding co-domination of _Sapium sabiferum_ due to its high regenerative capacity. _Quercus leucotrichophora_ which is rated high for fuel, timber and fodder, got restricted to the Oak regime in a very narrow range. In the same regime when the forest is able to meet fodder, fuel and timber requirements of the local community shift towards agro-horticulture is observed.

_Agro-horticulture :-_

In Kumaon even though variety of horticulture trees are available, the present study identified only two major systems _Pyrus communis_ and _Pyrus malus_ systems. Most of these systems are highly fragmented and poorly organized whilst others have modern agroforestry techniques incorporated into them. In Pine regime only _Pyrus communis_ is present whereas in Oak regime both the systems are evident. However, _Pyrus malus_ is the dominant agro-horticulture system in Oak regime.
Based on the survey, classification and characterization of agroforestry systems in the traditional societies of Kumaon. *Pyrus pashia* co-dominated by *Sapium sabiferum* in Pine regime, *Quercus leucotrichophora* co-dominated by *Pyrus pashia* and commercially viable *Pyrus malus* agro-horticulture system in Oak regime were found to be wide spread agroforestry systems. Therefore villages with these agroforestry systems were selected in the present study for detailed analysis for resource flow, energy and economic efficiency, nutrient budget and the village ecosystem structure and function.

**Resource flow analysis** :-

The agroforestry trees studied in details showed *Pyrus pashia* which had characteristics of early successional phase and *Quercus leucotrichophora* in climax vegetation. But *Sapium sabiferum* was an introduced species as a cover crop in tea nursing some 50-80 years ago is now naturalized. Large quantity of fuel wood is extracted from the pine regime agroforestry system, whereas in Oak regime large quantity of fodder is extracted. High level of crop diversity is maintained in the agroforestry systems of both pine and Oak regime through crop rotation in time and space together with co-existence of mono and mixed cropping practices.

To avoid crop losses due to nutrient removal incurred in each harvest farmers add organic manure which was prepared from the resources derived from the forest floor (leaf litter), fodder wastes, animal excreta and domestic wastes. The present study showed that in the traditional agroforestry systems of pine regime, where predominantly pine needle is used as animal bed, the yields of fine grain are higher in comparison to the Oak regime.
traditional agroforestry system. This is because: (a) Oaks are few and highly dispersed in relatively larger land holdings of the farmer and (b) the oaks are heavily lopped for fodder for animals (Therefore the input from the Oak system to the agricultural plots is limited) Besides, in the otherwise nutritionally poor pine regime system the human labour and organic manure inputs are also higher than in the Oak regime. Consequently the pine regime traditional agroforestry system perform better than Oak system, in terms of economic returns. The quality of resources in terms of C/N ratio (low) used in preparing manure is better in agroforestry system of Oak regime and agro-horticulture system based villages. It has also been observed that the resource use efficiencies in these villages reduces due to male out-migration.

Ecological and Economic efficiency :-

All the systems studied in Kumaon showed absence of inorganic inputs. Surprisingly, the seed and compost inputs are higher in traditional agroforestry system of Pine regime than agro-horticulture system even when the compost inputs to the fruit trees is taken into account. The monetary values of the inputs indicated the human labour is the most vital input to the system. As the opportunities for wage earning in the area are so meager, the farmers would have no option than to use it in their agricultural fields. Moreover, most of the agricultural activities are shared by women who are even restricted to the household activities in these societies.

The energy output from the traditional agroforestry system in pine regime and agro-horticulture system are higher than Oak regime. This is mainly due to high energy
obtained through removal of fuel wood through agroforestry tree species such as *Pyrus pashia* and *Sapium sabiferum* and fruit yielded by *Pyrus malus*. Monetary values of output are significantly higher in agro-horticulture as they represent cash crop (fruit) production. However, maximum resource is removed from the Oak trees of the traditional agroforestry system in Oak regime. This indicates preference of Oak species in the region.

The Monetary Output-Input balance of all the studied agroforestry systems (except agro-horticulture) showed negative values. When labour input, which is any case is free of the farmer, is included in the calculation. In terms of energetics, these systems, however, are ecologically sustainable.

*Nutrient Budget* :-

Compost is the main source of nutrient of all the agroforestry systems studied. The other biomass based inputs are tree leaf litter from agroforestry/horticulture trees on the crop field margin crop residue left back in the system. Among the traditional agroforestry system the one occurring in Pine regime had significantly higher nutrient inputs than that of Oak regime. However among the different cropping phases the maximum nutrient input was observed during the wheat phase and least during the Kharif (ragi) phase, in all the agroforestry systems. The nutrient budgets for the studied systems showed they are negative for most elements.
Village ecosystem structure and function :

Out of the three villages studied only Matela represents the traditional agroforestry system in Pine regime. Aucholi and Mardhura villages represent the traditional agroforestry and agro-horticulture systems respectively in Oak regime. Among the different subsystems forest provided 100% of the bedding material in all the villages and 36, 10 and 15% of fodder requirement in Matela, Aucholi and Mardhura respectively. The fuel wood support from forests was 27, 38 and 50% of the total requirements in Matela, Aucholi and Mardhura respectively.

In terms of input:output ratio of different subsystems agroforestry system, animal husbandry and domestic system of village Matela was highly efficient when compared with Aucholi among the traditional agroforestry villages. However, the agro-horticulture system in Mardhura was highly efficient but, its efficiency of domestic system was lower than other two traditional agroforestry based villages (Matela and Aucholi). The villages Aucholi and Mardhura located in the higher elevation (1950 meter elevation) had cows and goats only as part of the animal husbandry system. Apart from the fact that buffaloes are however to be stall fed and yield more manure, cows yield less and also left free to graze. Therefore the cows manure is often not accessible for agriculture. This could be the reason for the inefficiency of animal husbandry sub-system in these villages. Further decrease in population pressure with elevation increases the percapita land holding size.
Conclusion:

Existing agroforestry systems of traditional societies of Kumaon region is the best; the empirical knowledge gained through constant interaction with natural system (Forest) and with variety of interplay of socio-cultural and economic aspects. Structure composition and quality of the resources in both private (agroforestry systems) and Public (Forest) landuse systems are maintained in equilibrium. High diversity of resource (Oak regime) in the surrounding forest results in decrease in diversification on private land agroforestry systems. The attempt of diversification through cash crops (agro-horticulture systems) is still limited among the local community due to lack of market infrastructure. In the present scenario only six different agroforestry systems survive as a result of socio-cultural and economic needs within the altitudinal range of (1000 - 2000 m amsl), in which *Pyrus pashia* and *Sapium sabiferum* systems indicates fitness to *Pine regime* and *Quercus leucotrichophora* agroforestry system to *Oak regime*.

The detailed study of the above systems showed that, even though the resource quality of the *Oak regime* agroforestry is higher, the *pine regime* agroforestry system showed high in energy and economic efficiency. The village subsystems also showed similar trends and are comparable with the village with the agro-horticulture system in *Oak regime*. However the agro-horticulture systems are economically much more efficient than the agroforestry systems.

Structural and functional organization of agroforestry/agro-horticultural systems of Kumaon Himalaya need to be looked at the landscape level. All government
interventions are targeted towards replacement of traditional systems by cash crop dominated systems. Such interventions should not be over-emphasized because of risks of market and degradation of forest cover, so important for ecological functions in the mountains.