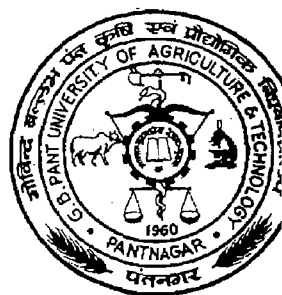


# RESOURCE USE EFFICIENCY AND OPTIMIZATION OF FARMING SYSTEMS INVOLVING AGROFORESTRY IN THE PLAINS OF KUMAON REGION

Thesis

Submitted to the

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By

***Preeti Tyagi***

*IN PARTIAL FULFILMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF*

**Doctor of Philosophy**  
(AGRICULTURAL ECONOMICS)

January, 2004

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---

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Each word will be insufficient to fully express my sense of appreciation for moral support, great favour, good wishes, acceptance and infallible love received from Neelu, Swati, Anju, Ritambhara, Mukta, Adarsh, Lalit and Fari .

I salute to Mr. Priyank Pathak who is no more in this world but whose charm, humour, emotional strength and exceptionally strong will power will always inspire not only me but all those who were privileged to be in his company even for once.

The love and best wishes of family of Shri R.K. Tyagi shall ever be cherished.

I would like to share the strain and joy of this work with my parents whose sacrifices; infinite love and patience made me, what I am today.

The financial assistance in the form of fellowship provided by the university is duly acknowledged.

I would like to pay my sincere thanks to Mr.D.R. Sharma who took all the pains to print this manuscript in a dexterous and careful manner.

At last I humbly place this study as a small token of tribute at the feet of Sri Mataji, whose blessings helped me to conduct and complete this work when it had seemed to be the most impossible task.

**Place: Pantnagar**  
**Date: January, 2004**

  
**(Preeti Tyagi)**  
**Authoress**

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**Dr. Jagdish Kumar**  
Professor

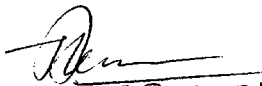
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## **CERTIFICATE**

This is to certify that the thesis entitled "**RESOURCE USE EFFICIENCY AND OPTIMIZATION OF FARMING SYSTEMS INVOLVING AGRO FORESTRY IN THE PLAINS OF KUMAON REGION**" submitted in partial fulfillment of the requirements for the degree of **Doctor Of Philosophy** with major in **Agricultural Economics** of the college of Post Graduate Studies, G.B.P.U.A&T, Pantnagar, is a record of bonafide research carried out by **Miss. Preeti Tyagi, Id.No.25749**, under my supervision, and no part of the thesis has been submitted for any other degree or diploma.


The assistance and help received during the course of this investigation and sources of literature have been acknowledged.

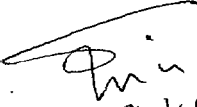
Pantnagar  
January, 2004

  
28-1-04  
**(Jagdish Kumar)**  
Chairman, Advisory Committee

# CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Preeti Tyagi**, Id. No. **25749**, a candidate for the degree of **Doctor Of Philosophy** with major in **Agricultural Economics**, agree that the thesis entitled "**RESOURCE USE EFFICIENCY AND OPTIMIZATION OF FARMING SYSTEMS INVOLVING AGROFORESTRY IN THE PLAINS OF KUMAON REGION**" may be submitted in the partial fulfillment of the requirements for the degree.

  
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Member

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## **INTRODUCTION**

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Our country was facing great crisis of food during sixties of 20<sup>th</sup> century. To achieve the self-sufficiency in food, increase in agricultural production was more the result of expansion of cropped area than increase in productivity till the beginning of the 1960's. This was done by turning grazing and forest lands into crop land, shifting the cropping pattern in such a way as to divert land under fodder crops to other crops.

The one way concern towards meeting food demand for growing population ignored the demand for fuel, fodder, timber etc. which was also increasing with population growth. But now when it is realized that emphasis on agriculture for more farm production without equal emphasis on forestry and grazing land is indeed counter productive and nonsustainable, we are left with little forest cover with which we can not tamper to meet the demand of forest products because of the concern for environmental security. The only option left is to utilize the cultivable land for both purposes i.e. to produce agricultural products as well as forest products.

Forests offer a wide range of both material and intangible benefits. They tend to offer possibilities for income generation in rural areas. They further provide a variety of environmental services like; conservation of biological diversity, protection of soil and water resources, support to agricultural productivity and sustainability, carbon sequestration (5-10 tonnes of CO<sub>2</sub>/yr)

and the mitigation of global warming, combating desertification and degradation of resources in arid and semi-arid regions, provision of shade, amenity and recreation. A large segment of India's population depends on forest for energy, housing, timber and fodder. Several industries are based on these forests like pulp and paper, plywood, match, dying and furniture industry.

India possess one per cent of the world's forest area, while caters 15 per cent of human and 19 per cent of the world's livestock population. The recorded forest area of the country is about 76.5 million hectare (1999) which is 23 per cent of the total geographical area. However, the tree cover is only about 64 million hectare (1999) which is 19.45 per cent of total geographical area of the country, out of which 38.6 million hectare has good forest cover having crown density of more than 40 per cent, 25 million hectare is degraded with crown density between 10 to 40 per cent and some forests are virtually blank (Sharma and Kumar, 1999).

A series of economic measures for rapid expansion in agriculture, industry, transport, employment and other infrastructure have viciously attacked and degraded our forests in last 50 years. Since independence country is loosing about 1.3 million hectare of forest cover every year. On the contrary, the demand of the wood in the country will touch 871.56 million cubic metre and that of industrial wood, 43.21 million cubic metre by 2010 while, the supply is projected to be 361.76 million cubic metre and 35.53 million cubic metre respectively for the same period. The demand supply imbalance for

paper and paper board will be 39.77 per cent by 2010. Further, there has been a quantum jump in recent years in the imports of forest products (7.87 per cent per annum) while the exports are negligible (1.75 per cent per annum). India historically self sufficient in forest products has become a major importer (Sharma and Kumar, 1999).

It is widely viewed that the forestry sector is likely to face increasingly difficult challenges in the future. Population growth, changes in population distribution, economic pressures and efforts to alleviate poverty and ensure food security will lead to more intense scrutiny of forest's actual and potential contribution to development and of the relative benefits of retaining land in forests versus converting it to other land uses. The most obvious challenge within the sector is that how to meet growing demand for forest products while at the same time safeguarding the ability of forests to provide a range of environmental services including among others, the conservation of biological diversity, mitigation of global climatic change & desertification and protection of soil and water resources.

One practical solution to combat these challenging problems lies in encouraging scientific agroforestry in non-forest lands which envisages introduction of trees on agricultural land and assumes significance of considerable dimensions. This will not only help meet the varied demands of fast growing population in sustainable manner but will also ensure environmental stability and provide economic security in India. Concern for

conservation of forests is amply reflected in the National Forest Policy of 1988 which puts several restrictions on transfer of forest land for non-forestry purposes. It recommends that the raw material requirement of forest based industries should be met by growing of trees through social forestry and farm agroforestry schemes without affecting food grain production adversely. This makes it necessary to accord highest priority to agricultural lands especially marginal lands followed by community and wastelands for development of agroforestry.

Agroforestry is a collective name for land use systems and technologies where woody perennials are deliberately used on the same land-management units as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence. It is an inter disciplinary, multi-sector approach of land use. Its prime objective is over all optimization and to protect the environment and maintain the ecological integrity. Agroforestry is primarily the technology of using perennial vegetation in combination with seasonal or perennial field crops, fodder, or other crops of economic value in agriculture. In the developed agroforestry systems, there are three components i.e. the woody perennials, the agricultural crops and the animals. However, in all the agroforestry systems the presence of the tree component is must and it plays the dominant role i.e. the productive roles (fuel, fodder, food, fruit and fertilizer) and the service roles (soil and moisture conservation, windbreak, shelter belts, shades etc.).

The farmers and land owners in different parts of the country integrate a variety of wood perennials in their crops and livestock production fields depending upon the agro-climatic conditions and local needs. Some popular agroforestry systems are shifting cultivation in North Eastern States and Orissa, Taungya, Homegardens, Plantation based cropping systems, scattered trees on farm lands, trees on farm boundaries, wood lots, trees on rangelands etc.

### **Problem statement**

Land is the most scarce resource. The land use planning, aimed at optimization of output per unit land area should be adopted with due care to have gradual restoration of lost productive vigour of the land. In recent times some people have seriously thought of combining different land uses. But little has been done to frame policies to integrate different sectors and to realise the maximum productive potential of people and land. The integration of one enterprise with another may help in increased production and more efficient use of various resources available at the farm. However, when more than one enterprises are combined together on the same resource base, they may interact among themselves. Interactions among crops, livestock, tree species etc. may occur in space, in time or in both space and time. These interactions can be negative, positive or both competitive and supplementary. Here arises the need to adopt the holistic approach for optimizing the use of various resources available at the disposal of farmers. The farming systems involving agroforestry have wide scope of optimization of the yield, improvement of land

productivity, employment generation and efficient use of resources, if farmers combine different components in careful and judicious way. The impact of different forms of farming systems involving agroforestry on the cropping pattern, resource productivity, input use, demand for labour, wage rates need to be studied to decide the efficient reallocation of scarce farm resources between the sub sectors of these farming systems such as crops, livestock and off course, agroforestry. Thus it will be significant to identify the different farming systems involving agroforestry to study their general features, their resource use efficiency and thereby develop an optimum enterprise mix according to farmer's preferences.

Situated at the foot hills of Himalayas, Bhabhar and Tarai tract has its own climatic and edaphic characteristics. In this area, soil moisture and drainage is very favourable to support tree vegetation. The observations of diagnostic and design survey of the area (**AICRP on AGROFORESTRY, 1995**) tell that the area has shortage of fuel wood, small timber for agricultural implements and household purposes, and green fodder during summers and early winters. The integration of trees on farms with agricultural crops can help fulfilling these requirements of farmers. Thus integration of trees on farm lands in various models of agroforestry is essential.

During the last decade agroforestry has gained importance as a part of farming systems in the plains of Kumaon region. However, farmers are still hesitant in adopting agroforestry at a very large scale because of lack of

awareness, problem in disposing off their tree produce and some adverse effect on agricultural production (**AICRP, Status Report, 1995**).

Moreover agroforestry needs a considerable investment in the beginning and starts giving returns after six to eight years. There is no pricing policy or price control mechanism at present. Delay in payments by the traders and industrialist is a common situation in most parts of India, farmers are forced to sell their produce at any rate in the event of high production as there is no facility of storage of wood (**Bandyopadhyay, 1997**).

Further agroforestry has its positive as well negative effect on agricultural production. It may not be benefited under all kind of farming systems.

Promotion of agro forestry in the plains of Kumaon region can be helpful to cater the need of forest based industries of the study area. It will also ensure efficient land use which focuses on sustainability and income generation in the area. Keeping in view these aspects it was thought necessary to identify existing farming systems involving agroforestry in the plains of Kumaon region and examine their profitability and resource use efficiency. Further optimization of these farming systems was planned to check out the potential of increasing income and employment by reallocation of prevailing resources specially land. It was also thought necessary to identify the constraints faced by farmers related to adoption of agroforestry.

Present study efforts to incorporate all these aspects in the form of different objectives to suggest some relevant policy implications for adoption of agroforestry in the plains of Kumaon region.

### **Objectives**

The specific objectives of the study are :

- (i) To identify and characterize important farming systems involving agroforestry in the plains of Kumaon region.
- (ii) To work out economics of important farming systems involving agroforestry.
- (iii) To examine resource use efficiency in the important farming systems involving agroforestry.
- (iv) To develop optimum farm plans for the important farming systems.
- (v) To study various constraints related to adoption of agroforestry.

## REVIEW OF LITERATURE

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An attempt has been made in this chapter to review the available literature forming the background of present study.

This chapter comprises of three sections which deal with (i) conceptual aspects considering agroforestry as a forceful tool to meet the present challenges of shortage of fuelwood, fodder, fibre, timber, employment etc. and to undermine the externality impact which can lead to environmental degradation. (ii) research studies related to development of optimum farm plan (iii) research studies related to analysis of resource use efficiency.

### **2.1 Research studies related to conceptual aspects and importance of agroforestry**

**Kamper and Krantz (1974)** defined farming system as the entire complex of resource preparations, decisions and activities which within an operational farm unit or a combination of such units, results in agricultural production.

**Agrawal *et al.* (1976)** examined the present status of agriculture in the hill district of Almora, U.P. with special reference to crop production, animal husbandry, agricultural extension services and socio-economic aspects. The results showed that the district had enough potential for generating surplus cash income in agriculture through the adoption of improved methods of crop and livestock husbandry to enable the farmers to buy the short fall in their food

requirements from the market. The study suggested some steps for improvement and emphasized the adoption of appropriate technology for tapping the water and energy resources and development of crops and livestock, suited to the special conditions of the region.

**Garg *et al.* (1978)** examined cropping intensity, area under irrigation, fertilizer use etc for the U.P. hills. They found that the area under high yielding wheat, paddy, maize, potato, fruits and vegetables varieties has increased. Vegetable, livestock, poultry and fishery enterprises had been recommended by them. The data used were highly aggregative and included the plain portion of some hill districts, where phenomenal progress in agricultural development has been achieved. Thus, their picture of cropping pattern in U.P. hills became highly distorted.

**Shah (1979)** concluded that the objective of an appropriate farming system in the hills should be to promote scientific resource use planning and management for increasing income, employment and quality of life without disturbing the ecosystem. The important activities like cultivation of field and plantation crops, animal husbandry, fisheries, sericulture, forestry, medicinal herbs, spices, fodder, grasses etc. should be determined according to soil capacity and potentiality of area and justified in terms of economic viability and social acceptability.

**Mathur and Sharma (1983)** stated that poplars are amongst the world's fastest growing industrial softwoods, which can be raised as pure or mixed plantations as well as in association with agricultural crops. They are mostly

multipurpose tree species, and their wood is in much demand for paper and pulp. Farmers were generally cultivating crops like sugarcane, paddy, wheat, maize, potato, gram, lahi, pea, soybean and for fodder-barseem, jowar, jai, maize and lobia, alongwith poplar plantations.

**Arther (1984)** evaluated the cost benefit of agroforestry on grazing lands. He applied SILMOD, a computer model to derive the potential returns from the forestry component of agroforestry. He observed that livestock carrying capacity decreases overtime as tree grows in size.

**Dadhwal *et al.* (1989)** described the socio-economic conditions of the Garhwal Himalayan region and the characteristics of existing agroforestry practices, and gave some suggestions for their improvement. They observed that farmers undertake cultivation of various crops with trees in mixture on the same piece of land. Farm animals and poultry formed as essential component of the systems. The intimate association of different species provided both subsistence and commercial products which gave additional income to the farmers.

**Luna (1989)** defined agroforestry as a sustainable land management system which increases the yield of the land, combines the crops and forest plants and/or animals simultaneously on the same unit of land and applies management practices that are compatible with cultural practices of the local population.

**Stocking *et al.* (1989)** reviewed the six existing cost-benefit studies on agroforestry and identified the key issues that would need to be addressed

before further advances can be made. The studies indicated the considerable potential for economic and financial analysis of agroforestry and underlined the need for further research on key issues like :

- establishing decision criteria especially distributional consequences on different income groups in society.
- Identifying, quantifying and valuing the costs and benefits. Issues of particular importance are how environmental and social benefits should be dealt with.

**Rao and Reyes (1990)** reviewed the current status of agroforestry in Asia and the far east and it was suggested that there is a small but growing interest in agroforestry. The examples of a farm forest schemes in India, the sloping agricultural land technology in the Philippines, the practice of intercropping agricultural crops with trees in China, and practice in the Pacific Island were used to demonstrate the impact on employment, labour productivity and income of possible interrelationship between trees and agricultural production.

**Sekar *et al.* (1990)** represented an economic analysis of Kapok cultivation in terms of cost of cultivation, fruit yield and economic returns. Data were derived from a sample of 10 farmers in the irrigated Metupalayam taluk of Coimbatore district. Results showed that the combination of Kapok and Cotton is particularly profitable as the cotton yield returns in the first two years while the Kapok is in its early stages of growth. Thus the Kapok-Cotton

combination yields promising results for income and employment generation as well as fulfilling the state's policy requirement of increasing forest cover.

**Verma (1990)** reported the results of a survey into two types of agroforestry i.e. peripheral planting and mixed planting in Gujarat. The survey was based on a random sample of 563 farmers, stratified by agroclimatic zones. This showed that peripheral planting is more popular than mixed planting, except under irrigated conditions when both are equally popular. Agroforestry has been strongly adopted by marginal, small and large farmers all over the state, but is most prevalent in the moderate rainfall zone (800-1000 m.m.) of middle Gujarat. Eucalyptus species are planted by 90 per cent of farmers in agroforestry systems. Farmers had a diversity of views on the effect of trees on annual crop yields. 51 per cent reported no change, 34 per cent a decrease, and 15 per cent an increase in crop yields.

**Maji (1991)** defined farming system as an organized unitary whole, composed of two or more interdependent and interacting parts, components or subsystems delineated by identifiable boundary or its environmental super system. It is a set of interrelated elements each of which is associated directly or indirectly with other elements and no subset of which is unrelated to any other subset. In fact, the interdependence, connectedness and interaction among the subsystems are the fundamental characteristics and the distinguishing features of a system.

**Singh and Roy (1991)** discussed the use of agroforestry to increase fodder production in India. They considered the integration of trees with

grazed pastures and forage crops and of fruit trees with pastures. They further described the socio-economic factors affecting forage production through agroforestry including technology transfer, land and tree tenure and competition for labour.

**Das (1992)** looked at the limitations of Farming System Research (FSR) specially considering research into perennial mixed crops. He concluded that there had been a gross neglect of Component Technology Research (CTR) and that CTR should be used to support FSR. Many FSR projects are found to be socially unacceptable because of the unwillingness and inability to collect baseline data and the lack of involvement of social scientists.

**Scherr (1992)** examined the challenges for more effective use of economic analysis in agroforestry development policy and programme design which included the following:

- (i) development of a theoretical framework for analysing the economic role and potentials of agroforestry in farming systems.
- (ii) development of better methods of incorporating agroforestry into models of household decision making.
- (iii) Generation of economic data on agroforestry including development of more effective and efficient methods of data collection.

Illustrations were drawn from field research in Western Kenya. He concluded that agroforestry economics is a field still in its infancy but with

challenges to be met in particular with regard to major land use changes expected in the next century.

**Nuberg and Evans (1993)** evaluated seven desktop farm models with different combinations of 5 production systems (seasonal cropping; coffee/pepper intercropping, also intercropped with seasonal crops for the 1<sup>st</sup>, 2<sup>nd</sup> year; a fodder/dairy system with alley cropped *Panicum maximum*; a eucalyptus woodlot intercropped with seasonal crops for the first 2 years and analog forest). They found that a model with 40 per cent seasonal crops, 20 per cent perennial crops (coffee/pepper) and 40 per cent analog forests offered the best solution. It was recognized that the socio-economic conditions that determine the appropriateness of this model in the Sri Lankan context are not universal.

**Barton (1994)** described the Sweden agroforestry systems and discussed their contribution to sustainability, biodiversity, productivity for market, soil conservation flexibility and population density support. He said that indigenous agroforestry systems are both ecologically and economically beneficial, but are not without some limitations. However, from the wealth of indigenous knowledge available and proposed new research it should be possible to adapt these systems to produce a model or blueprint for sustainable and productive agriculture for the new colonist.

**Hoekstra (1994)** examined the factors influencing the economic viability of the agroforestry systems of eastern and southern Africa. He inferred that the critical factor for the long term sustainability and potential expansion of the system is the time required to reap the benefits from newly

established trees. Therefore, research should be focussed on selecting and breeding "shorter period species". Govt. policy on prices of inputs such as fertilizers, seedlings and food crops were identified as major exogenous and management capability of farmers and labour, cost of seeds or seedlings as major endogenous factors affecting the economic viability of the system.

**Senkondo (1994)** examined the economic profitability of the selected agroforestry systems in the Uluguru mountain area of Morogoro, Tanzania. A survey of 80 farmers in the eastern and western parts of Uluguru mountains were made in generating the information base for the study. The results indicated that agroforestry practices were financially profitable and have remained viable over a wide range of increasing costs and declining benefits. The livestock component was found to increase the financial profitability of the systems. Improved technology, crop husbandry practices and appropriate intensification is required to help improve productivity.

**Thind *et al.* (1996)** suggested agroforestry as the best viable alternative land use system for sustaining agricultural productivity and ecological balance. They recommended poplar based agroforestry systems to prevent lowering of ground water table and serious nutritional deficiencies due to extensive rice-wheat rotation in central Punjab.

**Sharma and Sharma (1996)** explored the role of the forest department, wood based industries and banks in promoting farm forestry in the state of Punjab. Problems with the species of poplar and eucalyptus were outlined, notably the economic difficulties resulting from the glut of eucalyptus

production and consequent low prices received by the farmers, future issues and challenges for the long term management of farm forestry/agro-forestry in the state were discussed.

**Sharma (1996)** discussed agroforestry and its associated outputs from different types of practices on farm lands. He described agroforestry models developed, based on *Prosopis*, *Eucalyptus* and *Poplar*. These species specific models have been found to be economically viable land use propositions.

**Moore *et al.* (1997)** outlined the major types of agroforestry practices currently being developed in Australia, how they are being practiced and the technical, social and economic factors related to the broad scale adoption of agroforestry practices. The major types of agroforestry practices discussed were scattered trees on pasture, belts of trees on pasture and in crop land and block of trees for wood production and environmental benefits (shelter, control of water logging and salinity).

**Jain *et al.* (1999)** recommended intercropping of poplar with compatible seasonal crops not only for generating continuous supplementary income but also for compensating for the loss of agricultural commodities arising from the transfer of land to tree plantations. Wheat, sugarcane and vegetables in the early plantation stages and wheat in later stages too were suggested as intercrops.

**Pant *et al.* (1999)** studied the status and pattern of agroforestry practices in Tarai region of Kumaon. The study was made in three villages of Udham Singh Nagar district. Among the trees planted poplar emerged out to be the

most preferred species. Study of agroforestry patterns revealed that bund planting was predominant in the areas following with wayside and field plantations. In these villages 100 per cent farmers have adopted agroforestry practices thereby reducing pressure on the surrounding natural forests and shunning the misconception that tree planting has an inhibitory effect on agricultural crop growth.

**Kaur *et al.* (2000)** promoted agroforestry as a sustainable land use system that maintains or increases total yield by combining food crops with tree crops to produce more crop yield, fodder, energy biomass etc. on the same unit of land which also benefit in reduction of pressure on forests, efficient recycling of nutrient, reduction in nutrient leaching and soil erosion, improvement of microclimate etc.

**Quli (2001)** put forth the facts like India having just one per cent of the total global forest resources was sustaining around 16.1 per cent of the human and 15.1 per cent of the livestock population of the world. The extraordinary stress on the existing forest has reduced the per capita forest availability to the tune of only 0.07 hectare in the country.

He claimed agroforestry to be one of the most promising land management system, helping in the expeditious enhancement of productivity per unit area on sustainable basis.

**Gill and Lal (2002)** discussed the environmental benefits of multipurpose tree species. They informed that **Multi Purpose Tree Species (MPTS)** plants use the water and nutrient of sewage for their growth and

biodrains excess water without any harmful effect on the environment. Each tree acts as small biopump absorbing water from the soil and releasing it in the environment through transpiration.

Out of the tree species, poplar is the most responsive in utilizing sewage however, being deciduous it remains dormant in winter and can not biodrain effluent during winter month.

## **2.2 Research studies related to optimization**

*Singh et al. (1972)* observed that even under existing technology, a sufficient potential exists for improving agricultural production and augmenting the farm returns through proper allocation of existing resources on small farms in Nainital district. They observed this potential of increasing net farm returns to be 64 per cent in Nainital. Further the relaxation of cash constraints led to an additional increase in net farm returns to the extent of 6 per cent in Nainital. These findings revealed that there was inefficient allocation of available farm resources under existing technology on small farms.

*Eltonbary (1975)* used a static linear programming model to determine the optimum allocation of land, water and human resources in the Arab Republic of Egypt under three sets of conditions. The first involved an array of physical constraints on the three resources, the other versions incorporate institutional and marketing constraints. The findings suggested that substantial increase in net income could be attainable if it were possible to alter existing

institutional and marketing conditions. The agricultural labour force imposed no constraints under any of the settings but irrigation water generally does during certain months.

**Cheung and Augur (1976)** applied linear programming to the optimal allocation of forestry and other land uses, some of which (recreation) do not have an established market value as in farming. The determination of price charged was, therefore, achieved through the opportunity cost concept. Maximum total profit occurring from forestry, farming, recreation and multiple land use were estimated. The main objective was to stress on the importance of sensitivity analysis on input coefficients after a solution had been obtained. Profit coefficients derived from opportunity costs were found to be very sensitive to an initial small change.

**Dahia (1976)** used linear programming technique for 252 farm holdings of 14 sample villages in Haryana state and found that with a shift of acreage from economically less paying crops to economically more paying crops, the overall utilization of permanent family labour in peak periods increased by 10 per cent and farm income by 24 percent over the existing situation.

**Singh et al. (1977)** studied the impact on income and employment of varying level of dairy enterprises with crop farming and without availability of credit under existing and improved level of technology in Patiala district of Punjab. They used linear programming technique to develop optimum farm plan and found that there was a maximum increase in farm income of about 1.10 percent when one high yielding buffalo and three crossbred cows were

introduced in farm plan with improved level of crop technology. The optimum farm plan also resulted in increased employment of human labour.

**Natrajan (1978)** developed optimum crop plans for low, mid and high hilly areas of Himachal Pradesh and compared income under existing and optimal plans. No new crop activities appeared in optimal plan but acreage allocation was changed and cropping intensity declined slightly for the low and high hills. Optimal crop plans had fewer number of crops as compared to existing situations thus indicating a tendency towards specialization. The decline in crop intensity in low and high hills was attributed to lack of capital.

**Pandey and Bhogal (1980)** examined the possibilities of increasing income and employment on mixed farms in Aligarh district of Uttar Pradesh using linear programming technique, authors worked out the optimum plans with and without milch animals for small, medium and large farms respectively. The findings revealed that the number of milch animals that could be increased were three, six and six on small and large farms respectively. It was also observed that both income and employment could significantly be increased by adopting an optimum plan for crops and milk production on all the synthetic situations.

**Ramakrishnaiah (1980)** developed optimal agricultural plans for a period of five years, in Naurar Watershed Almora (U.P.) employing a multiperiod linear programming model. The objective function was to maximize the return over variable costs on all possible activities. The constraints of the model included the scarce resources land, labour, capital and

credit. The plan indicated that high yielding paddy and wheat were found to be less paying and hence could not compete with cash crops like vegetables potatoes and fruit crops. It was proposed to reduce the area under foodgrain crops to maximize farm income.

**Rai and Singh (1982)** used the linear programming technique to examine the income and employment effects of new crop production techniques with livestock in the dry farming areas of Haryana. Their findings revealed the scope for increasing farm income and employment by integrating livestock enterprises with crop farming by adoption of the new dryland agricultural production techniques. It also showed that the livestock enterprise was more labour intensive and needed to be further extended through intensive development programme.

**Johl and Kahlon (1982)** studied the application of linear programming technique in Indian farming conditions and showed that the linear programming can be applied in varying Indian conditions, and concluded that there existed a substantial potentiality of increasing farm income and production by reallocation of farm resources.

**Joshi and Agnihotri (1983)** developed a microlevel afforestation plan in perpetuity on waste and salt affected lands of village Panchayat of Katleheri district Karnal to meet the fuel wood demand of village society. To develop this long term plan multiobjective linear programming technique was used.

The objectives taken into account were maximization of fuelwood production, minimization of afforestation cost and maximization of employment opportunities for initial establishment of plantation.

The benefits considered were:

- Saving of macro soil nutrients through animal dung
- Enhancement of agricultural production
- Generation of employment opportunities

**Singh and Sharma (1988)** examined the existing levels of income and employment and the possibilities to increase them under five different systems on small farms in two districts of U.P. Data pertained to the year 1983-84. The five farming systems examined were:

- (i) Cropping
- (ii) Crop + dairy
- (iii) Crop goat
- (iv) Crop + dairy + goat
- (v) Crop + dairy + poultry

Linear programming model was used to determine the optimum return for each of the five systems. The optimum systems were developed with the incorporation of borrowing and improved technology under two situations : (i) Livestock numbers restricted to the average number maintained on 10 per cent of the farmers having maximum number and (ii) Livestock number not restricted. The existing farming systems were then compared with the optimum plans. Under the optimal plan total income increased by 11 percent and family

labour employment by 28 percent under crop + dairy, 29 per cent and 31 percent under crop + goat, 52 and 21 percent under crop + dairy + goat and 11 percent and 17 percent under crop + dairy + poultry respectively.

**Sankhayan and Cheema (1991)** suggested that the accuracy of the results of the optimum farm plans depends on the correctness of using logic in model building. They concluded by their study that:

- (a) It is essential in all the models not to include the cost of those inputs in the working capital coefficients for which separate buying activities are provided in the model.
- (b) It is optimal to use interest as a component of individual working capital coefficients provided, the form of the model used is consistent with such a situation.

**Vijay Lakshmi (1992)** used linear programming to prepare an optimal tree combination plan for afforestation to meet the varying fuel and fodder requirements over time of the people of the area. The study was conducted in Hawalbagh block of district Almora. It was observed that the net social benefits were maximized when plan attempted to fulfil only firewood demand. This indicates that fulfillment of fuel demand was best compatible with other benefits obtained from trees.

**Dridi *et al.* (1994)** examined the effect of integration of dairy production into irrigated farms in the North West of Tunisia. A two step mixed multiobjective linear programming model was used. The first step enabled the determination of the optimal herd size taking into account both animal feed

needs and alternative marketable crops. The four objectives considered were (i) maximization of gross returns (ii) optimization of deviational variables between animal needs and forage supply and complementary ration. For the second step, additional capital restraints were introduced. The results showed that the complementary ration currently used did not need actual animals. Further intensification of the production system could only be achieved by introducing forage crops with a shorter cycle.

**Goswami (2002)** used Linear Programming Model to develop the optimum farm plan for the farming systems like valley land cultivation, horticulture, terrace cultivation, plantation crops, forestry and fodder and livestock at the existing and improved level of resources. The study area was West Garo Hills of Meghalaya. The results showed that there existed the possibility of further increasing the farm income in the existing situation with the supply of additional human labour and capital. Adoption of optimum farm plans help in augmenting the income and employment of the tribal farmers by bringing the entire jhum land under rubber cultivation while preserving the land resource from degradation by preventing soil erosion.

**Singh (2002)** conducted a study to determine the economic benefits obtained by farmers from livestock, crop and farm forestry enterprises. 400 tribal farmers belonging to different groups in Kanle block, Ranchi district, Jharkhand, were surveyed in 1996-97 and 1997-98. Income analysis showed that crop, livestock and farm forestry enterprises were primary sources of farm income of the farmers. The average annual gross income from these

enterprises were found to be Rs.18158 per farm. The contribution of crop husbandry, livestock and farm forestry was 71 per cent, 19 per cent and 8 percent, respectively.

**Mathur (2003)** examined the various existing systems/ enterprise mix practiced on different size groups of farms in the Amroha block of district J.P. Nagar of U.P. and developed the most remunerative farm plans involving these enterprise mix in the context of improving the existing socio economic conditions of the farmers. It was observed that the diversification of enterprises was more pronounced on small farms as compared to medium and large farms. There existed scope of increasing farm income and employment through rational allocation of resources and combination of enterprises.

### **2.3 Research studies related to resource use efficiency**

**Sankhayan and Sirohi (1971)** used production function analysis work as an analytical tool for analyzing resource productivity and allocation efficiency on seed potato farms in Himachal Pradesh. Two types of production functions, namely Cobb-Douglas and Quadratic were used to express the relationship between output and the various inputs for each crop. However, before doing so the zero order correlation matrices were worked out and then correlation coefficients were estimated for multicollinearity. Cobb-Douglas function was found to be best suited to express the relationship between output and the various inputs for each crop.

**Singh and Pandey (1971)** in their study on “Resource use efficiency in a dry farming area of Banda district of Uttar Pradesh” found that farmers were handicapped with inadequacy of growth promoting inputs such as manures, fertilizers and irrigation facilities and were using the conventional input labour in excessive quantity owing to non-availability of other non-farm employment opportunities.

**Singh and Patel (1974)** observed in their study based on data of 120 farmers adopting new technology from Meerut district of Uttar Pradesh, that the small farmers had maximum allocating efficiency. Comparison between computed optimum level of input and the existing level of input use and returns on different size groups of farms indicated that irrigation was the most profitable resource.

**Singh (1975)** in a study based on data from Deoria district of Uttar Pradesh for the year 1967-68 used production function approach to analyse resource use efficiency on small and large farms. The study indicated that there were only a few significant inefficiencies in the present use of factor inputs on the average farms. However, the elasticity coefficient of most of the inputs differed considerably between the small and large farms. Constant returns to scale was also observed to prevail for both the groups of farms.

**Dhawan and Bansil (1977)** studied rationality of the use of various factors on different sizes of farms in the Punjab. The hypothesis that farmers were rational in resource use on various categories of farms was tested by using a functional approach. The study indicated that land was efficiently used on

small and medium farms. However, on large farms, there was scope for extending the use of land. The small farmers were observed to be rational in spending on implements and machinery, milch animals, seeds and manures and fertilizers. The medium and large farmers were observed to be rational in their expenditure on all resources, except on irrigation structure in the case of medium farms.

**Gosh (1980)** studied labour use efficiency in Ferozpur district of Punjab state. The study indicated that on small and medium farms, the marginal value productivity of labour was almost equal to the wage rate and thereby suggested a situation of quasiequilibrium and a fair degree of allocative efficiency on these farms. However, on large farms, labour was not used efficiently.

**Rahim (1982)** evaluated and compared resource use efficiency under unterraced, traditionally terraced and improved terraced conditions as terracing is an important mechanical soil conservation measure to crop land. The study was conducted in Ramganga catchment in Uttar Pradesh hills. In all the cases marginal value products (considering *ceteris paribus*) under improved terrace condition were higher than that of traditional terrace and unterraced conditions. The production function under improved terrace condition have shifted upward from those of unterraced and traditional terrace condition with respect to all the considered factors.

**Sharma (1986)** used linear programming to optimize farm resource use and examine the changes in income in different farming systems, prevalent on

the large farms in Gunnaur block of Badaun district U.P. He observed that there existed no possibility of increasing income of the farmers with restricted supply of resources of cash and labour. Labour emerged out to be more limiting constraint than cash on the large farms, irrespective of the farming system adopted, which limits the scope of increasing farm income.

**Kandpal (1988)** made an optimum plan for afforestation on the community land of Almora district. He obtained different results in terms of tree combination plans in alternative formulations of objective functions in terms of profit maximization and cost minimization. He preferred the profit maximization over the later. Considering the wide-spread unemployment in the area leading to a large migration for employment, he assumed that the labour would be available for forestry purposes when required. Economics of different tree species were also worked out at the interest rate of 12 per cent.

**Kecskes (1989)** used data on the inputs and outputs of 34 wine producing farms in Hungary over the period 1981-85 and assessed various methodologies for optimization of resource use. Results indicated that the Cobb-Douglas Production function is best suited to the problem of input output optimization on the farms surveyed.

**Mandal *et al.* (1995)** compared per hectare cost, returns, productivity and estimated the impact of farm size on employment. The study used the empirical data collected through a lengthy intensive farm survey of 220 sample farmers in an area of Mymen Singh district in Bangladesh. The study showed that medium farms obtained the highest yield and gross margins despite using

the least amount of inputs. They were also technically more efficient. The study also showed that there is scope to increase the use of fertilizers despite its higher price in recent years. It is also found that small farms created more employment opportunities and medium farms used resources more efficiently in the study area.

**Sahu *et al.* (1996)** evaluated productivity and nitrogen use efficiency of wheat for two years under the canopies of 6-8 years old plants of four tree species (Poplar G-3, Eucalyptus hybrid, Guthel and Jameur). The reduction in grain yield of wheat was maximum under poplar. On the other hand straw yield and nitrogen content in both wheat grains and straw were higher than in the sole crop. All the parameters of N-use efficiency, i.e. recovery fraction, physiological efficiency and agronomic efficiency, decreased continuously with increasing level of nitrogen application.

**Gaddi *et al.* (2002)** estimated the technical and economic efficiency in groundnut production in Karnataka. Study utilized the primary data collected from the sample farmers selected through multistage sampling technique during the year 1996-97. Production function analysis revealed that human labour, bullock labour, plant nutrients and capital were the most important determinants of groundnut production. Results of the study revealed that farmers achieved relatively higher output efficiency in groundnut production. All the inputs were used in higher quantity than the frontier usage level. Profitability ratio analysis showed that only bullock labour on small farms and human labour on large farms were optimally used. Thus study suggested the

need for reallocation of expenditure among the different inputs based on the profitability ratio.

**Gangwar (2002)** analyzed the resource use efficiency on selected farms under irrigated and rainfed conditions in central U.P. He observed that the expenditure on fertilizers, manure and plant protection chemicals contributed significantly to crop productivity. The regression coefficients of expenditure on human labour, machinery, seed and fertilizer were found positive and significant for vegetables. The assured, timeliness and scientific management of irrigation water enhanced the productivity of land and other resources in central U.P.

Above cited literature clearly indicated that no study is directly integrating all the economic aspects which deal with the development of an optimum farm plan for a farming system involving agroforestry. Further the data specific study are almost rare which can tell us the present status of agroforestry in the plains of Kumaon region and can tackle the problem faced by the farmers in the stated area. To deal with the economic aspects of this particular region and to formulate an ideal farm plan to trap the potential of increasing the income of the farmers of the plains of Kumaon region and further to share the responsibility of maintaining a serene environment, this particular study is needed. Further the studies considering conceptual and methodological aspects throw light on the need of a fresh study on agroforestry keeping in view the objectives a farm planner wants to accomplish.

## **DESCRIPTION OF STUDY AREA**

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Uttaranchal as a new state had been carved out of the northern part of Uttar Pradesh on 9<sup>th</sup> Nov 2000. It consists of two region namely Kumaon and Garhwal between Himalaya and Shivalik ranges. Our area of interest is only plains of Kumaon region, which comprises Udham Singh Nagar district, a considerable portion of Nainital district and small portion of Champawat district. The present chapter has been devoted to give a general background of the study area comprising of the geographical features, agriculture and animal husbandry situation.

### **Physiography**

The plains of Kumaon region consists of (i) The Tarai and (ii) The Bhabar.

#### **Tarai**

The northern fringe of the Indo-Gangetic plains, waterlogged in older times is known as Tarai. This 10-25 Km wide marshy tract in the South of Bhabar running parallel to it. It is marked by reemergence of the under ground streams of the Bhabar belt. The reemerged water converts large areas along the rivers with ill-drained marshy land of excessive dampers covered with thick forest giving shelter to a variety of wild life. Due to availability of fertile soils, hot climate, coupled with abundant water, this, once, densely forested Tarai belt has been the homeland of Tharus, Buksas and Gujjars. The Tarai soils are rich in nitrogen and organic matter but are deficient in phosphate. These soils are

generally covered by tall grasses and forests but are suitable for number of crops, such as wheat, rice, sugarcane, jute and soybean under reclaimed conditions. The Tarai today is one of the most developed parts of the country.

### **Bhabar**

The Bhabar is 10-20 Km wide belt between the Shivalik and Tarai, running in East-West direction along the foot of the Shivaliks with a remarkable continuity from the river Indus to the Tista. Rivers descending from the Himalayas deposit their load along the foothills in the form of alluvial fans. These fans consisting of gravels and unassorted sediments have merged together to build up the Bhabar belt, which form the northern boundary of the great plains. The porosity of the pebble studded rock beds is so high that most of the streams sink and flow underground. Therefore the area is marked by dry river courses except in the rainy season. Consequently, the belt faces acute problem of water scarcity. The Bhabar belt is comparatively narrow in the east and extensive in the western and north western hilly region. Because of scarcity of water and dry river courses this region is sparsely inhabited.

### **Soils**

Alluvial soils are more common in the Tarai zone as they are deposited by rivers and rivulets. These are mixed with boulders, gravels and pebbles in the Shivalik valleys, doon valleys and Bhabar region. Alluvial soils are loam to sandy loam in texture having low organic matter and nitrogen contents and low to medium available phosphorus and potassium contents.

## **Temperature**

The Tarai, Bhabar and low-lying valleys have hot and humid climate. The mean temperature in the month of January is about 21<sup>0</sup>C in the sub mountain belt of Tarai and Bhabar . June registers highest temperature around 40<sup>0</sup>C in Tarai and Bhabar.

## **Precipitation**

Nearly all forms and methods of precipitation from rain to hail and snow can be more or less observed in the region more particularly the orographic type, which is definitely the most wide spread and dominant type of precipitation occurring through monsoon . The maximum rainfall is received during the rainy season characterized by high cloudiness and torrential rainfall. The monsoon commences after mid June and continues up to September. The average annual rainfall is 150 c.m. in Tarai- Bhabar belt.

Further description in this chapter is confined to U.S.Nagar district and Nainital district, which forms the major portion of plains of Kumaon region .

### **3.1 U.S.Nagar**

#### **3.1.1 Population Structure of U.S. Nagar district**

According to 1991 census, the total population of U.S.Nagar is 957450 with the rural population of 645470 and urban population of 311980. The percentage of schedule castes and schedule tribes in the total population is 13.43 per cent and 9.0 per cent respectively. The ratio of male to female is 1150: 1000. The population structure of the district is given in Table3.1.1

**Table 3.1.1 : Population structure of U.S.Nagar of Uttaranchal (1996-97)**

S.No.	Particulars	Number	Percentage of total population
1.	Rural population	645470	67.41
2.	Urban population	311980	32.58
3.	Male population	513740	53.67
4.	Female population	443710	46.34
5.	Scheduled caste	128640	13.43
6.	Scheduled tribe	86630	9.04
	<b>Total population</b>	<b>957450</b>	<b>100.00</b>

Source : Statistical Bulletin, U.S.Nagar district, Uttaranchal, 2001

### 3.1.2 Occupational Distribution of the population

The number of persons in different occupational categories for the district is presented in Table 3.1.2. The Table indicates that there are 36.4 per cent farmers and 26 per cent agricultural labourers. Thus about 62.4 per cent workers are engaged in agriculture.

**Table 3.1.2: Number of persons in different occupations in U.S. Nagar district Uttaranchal (1991)**

S.No.	Particulars	Total Number	Percentage of total workers
1.	Total workers	350426	100.00
2.	Farmers	127555	36.40
3.	Agricultural labourers	91110	26.00
4.	Construction	7709	2.20
5.	Transportation, storage and communication	10162	2.90
6.	Plantation	7008	2.00
7.	Trading	26982	7.70
8.	Others	79900	22.80

Source: Statistical Bulletin, U.S.Nagar district, Uttaranchal, 2001

### 3.1.3 Education

The district has 915 junior basic schools, 229 senior basic schools. 96 intermediate colleges and four degree colleges. Besides these, there exists one University and one polytechnic college in the district for vocational education. The educational attainment of the population is given in Table 3.1.3. The overall literacy is quite high, 65 per cent according to 1996-97 data.

**Table 3.1.3 : Literacy rate in U.S.Nagar district, Uttaranchal (1996-97)**

Sex	Educated population	Literacy percentage
Male	318518	62
Female	306159	69
Total educated persons	624677	65

Source : Statistical Bulletin, U.S.Nagar district, Uttaranchal, 2001

### 3.1.4 Climate and Rainfall

The climate of U.S.Nagar is humid sub-tropical with hot dry summers and cold winters. The temperature exceeds 40°C in summers and it falls as low as 1.8°C in winters. The average rainfall is 1300 mm, out of which more than 85% precipitation is received during June to September. The mean relative humidity at 7:00 A.M. remains nearly constant at above 90% from July to March and then decreases to about 50% up to May. The mean bright sunshine hours are lowest (2.0 hrs/day) in December and January and then duration continuously increases to 10-hrs/ day during May. The wind velocity is also low during December-January while maximum wind velocity is observed from April to June.

### 3.1.5 Soils

The soils in the study area vary from clayey loam to sandy loam depending upon the topography of the land. The soils found on the higher topography are mostly sandy loam in texture with good to excessive drainage and are subject to erosion. Those in low-lying situations are finer in texture showing impeded structure with accumulation.

### 3.1.6 Land Use Pattern of U.S. Nagar

The land use pattern of U.S.Nagar district is given in the following Table 3.1.4.

**Table 3.1.4 : Land Use Pattern in U.S. Nagar (1999-2000)**

S.No.	Particulars	Area (hectare)	Percentage of total Geographical area
1.	Total geographical area	278678	100.00
2.	Area under forest	93205	33.44
3.	Barren and unculturable land	1117	0.40
4.	Land use other than cultivation	24742	8.88
5.	Culturable waste	3653	1.31
6.	Permanent pastures and grazing land	18	0.006
7.	Other herbs, trees, orchards etc	1022	00.36
8.	Current fallow	2412	00.87
9.	Other fallow	2485	00.89
10.	Kharif land	150269	53.92
11.	Rabi land	98045	35.18
12.	Zaid land	8945	3.21
13.	Net sown area	150024	53.83
14.	Area sown more than once	107240	38.48
15.	Gross cropped area	257264	
16.	Cropping intensity	171.48 %	

Source: Statistical Bulletin, U.S.Nagar district, Uttaranchal, 2001

### 3.1.7 Irrigation sources

The water table in the area being high, artisan wells were very popular and common in the past on account of uneven distribution of rainfall. Other sources of irrigation are also well developed. Table 3.1.5 shows different irrigation sources and source wise irrigated area. There are 1063 kilometre long canals, 7058 private tubewells, 249 State Government's tubewells, 2889 wells, 20656 pump sets and 104 ponds. The total irrigated area formed 95.49 per cent of the net cultivated area in 1999-2000. Tubewells happen to be most popular and important source of irrigation in this study area as they accounted for as much as 57.57 per cent of the net irrigated area. Then comes the canal, which irrigated 23.87 per cent of the net irrigated area. Area irrigated by other sources is negligible in this district.

**Table 3.1.5: Source wise irrigated area in U.S. Nagar district, Uttaranchal (1999-2000)**

S.No	Source of irrigation	Number/ Length	Net irrigated area in ha	Percentage of net irrigated area
1.	Canals	1063*	34201	23.87
2.	Tubewells			
	a. Private	7058	82483	57.57
	b. State Government	249	11098	7.75
3.	Pump sets	20656	1884	1.32
4.	Wells	2889	12100	8.45
5.	Ponds	104	96	0.07
6.	Other		1407	0.98
	Net irrigated area		143269	100.00

Source: Statistical Bulletin, U.S.Nagar district, Uttaranchal, 2001

\*The figure denotes length of the canal in kilometers

### 3.1.8 Manuring and fertilization

Mostly nitrogenous fertilizers along with some deficit micronutrients are used, e.g. Zn from ZnSO<sub>4</sub> in paddy crop. Besides chemical fertilizers, farmers also use FYM in form of compost and practice green manuring to maintain the fertility of soil. About 69857 metric tonnes of chemical fertilizers were distributed in the district in 1999-2000 in which nitrogen was 45719 metric tonnes, phosphorus was 13748 metric tonnes and potassium was 10390 metric tonnes.

### 3.1.9 Area under different crops

Table 3.1.6 shows the area under different crops grown in U.S.Nagar district during 1999-2000. It indicates that paddy occupies largest area under cultivation i.e. 41.99 per cent. Paddy is followed by wheat, sugarcane, oilseeds and pulses.

**Table 3.1.6 : Area under different crops in U.S.Nagar district, Uttaranchal (1999-2000)**

S.No	Crops	Area in hectares	Percentage of gross cropped area
1.	Paddy	108017	41.99
2.	Wheat	83029	32.27
3.	Barley	69	0.03
4.	Oat	306	0.12
5.	Maize	704	0.28
6.	<b>Total cereals</b>	191819	74.56
7.	Pulses	3771	1.46
8.	<b>Total foodgrains</b>	195590	76.03
9.	Oilseeds	6087	2.37
10.	Sugarcane	38098	14.81
11.	Potato	732	0.28
12.	Kharif fodder	5230	2.03
13.	Rabi fodder	4067	1.58
14.	Zaid fodder	2621	1.02
15.	Other	4839	1.88
	<b>Total</b>	257264	100.00

Source: Statistical Bulletin, U.S.Nagar district, Uttaranchal, 2001

### 3.1.10 Average production and productivity

Average yield of 633.04 quintals per hectare for sugarcane, one of the most important crop besides rice and wheat, was observed in 1999-2000 (Table 3.1.7). Among cereals, the production of paddy but the productivity of wheat was highest being 315856 metric tonnes and 33.09 quintals per hectare, respectively. Pea among pulses has highest production and productivity both. Among oilseeds sunflower was having highest production and productivity viz. 224 metric tonnes and 9.02 quintals per hectare respectively.

**Table 3.1.7 Average production and yields of selected crops in U.S. Nagar district, Uttaranchal (1999-2000)**

S.No	Crops	Production (metric tonnes)	Average yield (Quintals per hectare)
1.	Paddy	315856	29.24
2.	Wheat	274722	33.09
3.	Barley	175	25.30
4.	Oat	-	4.47
5.	Jowar	-	10.00
6.	Maize	1020	14.49
7.	Sugarcane	2411756	633.04
8.	Potato	16519	225.36
9.	Bajra	-	10.00
10.	Urd	75	4.87
11.	Lentil	1518	8.63
12.	Gram	196	9.72
13.	Pea	2054	13.84
14.	Arhar	58	7.48
15.	Moong Kharif	10	2.81
16.	Moong Zaid	22	5.41
17.	Lahi	3332	6.16
18.	Til	-	1.34
19.	Groundnut	19	3.51
20.	Sunflower	224	9.02
21.	Soybean	86	7.65
	Other	201	-

Source: Statistical Bulletin, U.S.Nagar district, Uttaranchal, 2001

### 3.1.11 Livestock

Table 3.1.8 gives the category wise distribution of the livestock population in district U.S. Nagar during 1999-2000

The Table reveals that the total livestock population in the district was estimated at about 6 lakh. During the year 1999-2000, there were 271314 cattle, 4084 sheep, 43606 goats and 296009 poultry birds.

The Table further indicates that in the total livestock population of the district, cattle accounted for 45.23 per cent. Poultry and goats accounted for 7.27 and 49.35 per cent respectively of the total livestock population.

**Table 3.1.8: Distribution of livestock population in U.S.Nagar district, Uttaranchal (1997-98)**

S.No	Livestock	Population	Percentage
<b>A.</b>	<b>Cattle</b>		
	Adult male	41461	06.91
	Cross breeds	7421	01.23
	Adult female	98377	16.40
	Cross breeds	19865	03.30
	Young stock	87160	14.52
	Crossbreeds	17020	02.84
	<b>Total cattle</b>	<b>271314</b>	<b>45.23</b>
<b>B.</b>	<b>Other animals</b>		
	Sheep Desi	4006	00.67
	Sheep cross breeds	78	00.02
	Goats	43606	07.26
	Horses	2540	00.42
	Pigs	4048	00.66
	Poultry	296009	49.35
	<b>Total other animals</b>	<b>328482</b>	<b>54.77</b>
	<b>Total Livestock Population</b>	<b>599796</b>	<b>100</b>

Source: Statistical Bulletin, U.S.Nagar district, Uttaranchal, 2001

## 3.2 Nainital

### 3.2.1 Population structure of Nainital district

According to 1991 census, the total population of Nainital district was 582730 with rural population of 391740 and urban population of 190990. The percentage of schedule castes and schedule tribes in the total population was 19.68 per cent and .58 per cent respectively. The ratio of male to female was 1.14:1. The population structure of the district is given in Table3.2.1.

**Table 3.2.1: Population structure of Nainital district , Uttaranchal (1991Census)**

S.No	Particulars	Number	Percentage of total population
1.	Rural population	391740	67.22
2.	Urban population	190990	32.78
3.	Male population	310060	53.21
4.	Female population	272670	46.79
5.	Scheduled caste	114680	19.68
6.	Scheduled tribe	3390	00.58
	<b>Total population</b>	<b>582730</b>	<b>100.00</b>

Source : Statistical Bulletin, Nainital district, Uttaranchal, 2001

### 3.2.2 Occupational distribution of the population

The number of persons in different occupational category for the district is presented in Table3.2.2. Table indicates that there are 47.88 per cent farmers and 7.82 per cent agricultural labourers of total workers. Thus about 55.7 per cent of the total workers are engaged in agriculture.

**Table3.2.2: Number of persons in different occupations in Nainital district, Uttaranchal (1991)**

S.No.	particulars	Total Number	Percentage of total workers
1.	Total workers	206239	100.00
2.	Farmers	98756	47.88
3.	Agricultural labourers	16127	07.82
4.	Construction	7951	03.86
5.	Transportation, storage and communication	7826	03.79
6.	Plantation	8686	04.21
7.	Trading	19009	09.22
8.	Others	47884	23.22

Source: Statistical Bulletin, Nainital district, Uttaranchal, 2001

### 3.2.3 Education

The district has 1081 junior basic schools, 319 senior basic schools, 118 intermediate colleges and 3-degree colleges. Besides these, there exists one University and one polytechnic college in the district for vocational education. The educational attainment of the population is given in Table3.2.3. The overall literacy was 55.1 per cent in 1996-97.

**Table 3.2.3: Literacy rate in Nainital district, Uttaranchal (1996-97)**

Sex	Educated population	Literacy percentage
Male	201477	64.98
Female	119620	43.87
Total educated persons	321097	55.10

Source: Statistical Bulletin, Nainital district, Uttaranchal, 2001

### **3.2.4 Climates and rainfall**

In January the mean maximum temperature varies between  $9.7^{\circ}$  to  $10.2^{\circ}$  C and in May it varies from  $23.5^{\circ}$  to  $24.8^{\circ}$  C . Annual relative humidity varies from 60-70 per cent. Rainfall is heavy in hills and foothills. The areas of heaviest downpours lie in this district. The annual total rainfall is more than 1800 mm., out of which, more than 90 per cent precipitation is received from summer monsoon i.e. June to mid-October, 8 per cent from the winter cyclones i.e. January-March, and the rest from the retreating monsoon in mid October-December and pre monsoon showers in April-May.

### **3.2.5 Soils**

The soils have developed on rocks with biotic schist and phylitic materials, under cool and moist climate and temperate forest cover. The soils are generally shallow and gravelly. Deeper soils are confined to some hill slopes and valleys. The soils are brown to greyish brown and dark grey in colour and moderately acidic to neutral in reaction. Organic matter status, phosphorus content and potassium content are medium in soil. Bhabar soils are shallow with loamy sand and to loam texture with abundant quantities of gravels and stones. Water percolation through profile is very rapid and nutrient and moisture retention capacity and fertility of soils are low.

### **3.2.6 Land use pattern of Nainital district**

The land utilization pattern of Nainital district is given in the following Table 3.2.4.

**Table 3.2.4 : Land Use Pattern in Nainital district (1999-2000)**

S.No.	Particulars	Hills		Plains	
		Area (hectare)	% of total geographical area	Area (hectare)	% of total geographical area
1.	Total reported Geographical area	92917	100.00	95732	100.00
2.	Area under forest	41473	44.63	38296	40.00
3.	Barren and unculturable land	1759	01.89	1266	01.32
4.	Land use other than cultivation	2426	02.61	4253	04.44
5.	Culturable waste	13914	14.97	12878	13.45
6.	Permanent pastures and grazing land	714	00.77	497	00.52
7.	Other herbs, trees, orchards etc	10845	11.67	5461	05.70
8.	Current fallow	564	00.61	427	00.45
9.	Other fallow	3383	03.64	1007	01.05
10.	Kharif land	13395		30434	
11.	Rabi land	11661		25190	
12.	Zaid land	-		1781	
13.	Net sown area	17839	19.20	31647	33.06
14.	Area sown more than once	7259		25716	
15.	Gross cropped area	25056		57405	
16.	Cropping intensity	140 %		181%	

Source: Statistical Bulletin, Nainital district, Uttaranchal, 2001

### 3.2.7 Sources of Irrigation

Table 3.2.5 shows source wise irrigated area. There are 343 km long canals in the hill region while in the plains they are 561 km. Besides canal there were 91 private tubewells, 420 State Government's tubewells, 2889 wells, 270 pump sets and 459 ponds in the plains of Nainital district. The total irrigated area formed 75.24 per cent of the net cultivated area in 1999-2000 in the plains. Canals happen to be most important source of irrigation in this part of study area as they accounted for as much as 76.16 per cent of the net irrigated area. Then comes the

State govt. tubewells, which irrigated 14.14 per cent of the net irrigated area.

Area irrigated by other sources is negligible in this district.

**Table 3.2.5: Source wise irrigated area in Nainital district, Uttaranchal (1999-2000)**

S.No	Source of irrigation	Hills			Plains		
		No.	Net irrigated area in ha	Percentage of net irrigated area	No.	Net irrigated area in ha	Percentage of net irrigated area
1.	Canals	343*	6068	95.54	561*	18135	76.16
2.	Tubewells						
	a. Private				420	1716	07.21
	b. State Government	-			91	3366	14.14
3.	Pump sets	61			270		
4.	Gul	371	283	04.45	790	595	02.50
5.	Ponds	1745			459		
6.	Hydum	114					
	Net irrigated area				6351		

Source: Statistical Bulletin, Nainital district, Uttaranchal, 2001

\*The figure denotes length of the canals in kilometers

### 3.2.8 Manuring and fertilization

About 10776 metric tonnes of chemical fertilizers were distributed in the district during 1999-2000 in which almost 94 per cent was distributed in the plains. Nitrogen was 6097 metric tonnes, phosphorus was 2819 metric tonnes and potassium was 1178 metric tonnes in the plains of Nainital district. Per hectare fertilizer consumption was 459.22 kg in 1999-2000.

### 3.2.9 Area under different crops

Table 3.2.6 shows the area under different crops in Nainital district. It indicates that in the plains wheat occupies largest area under cultivation i.e. 35.36 per cent. Wheat is followed by paddy and maize. Among other crops, sugarcane

covers highest area i.e. 11.43 per cent of the total cropped area. Pulse area is negligible in the plains of Nainital district.

**Table 3.2.6: Area under different crops in Nainital district, Uttarakhand (1999-2000)**

S.No	Crops	Hills		Plains	
		Area in hectares	Percentage of gross cropped area	Area in hectares	Percentage of gross cropped area
1.	Paddy	4402	17.57	11105	19.35
2.	Wheat	9076	36.22	20298	35.36
3.	Barley	769	03.07	131	00.23
4.	Oat	448	01.79	167	00.29
5.	Maize	4503	17.97	3455	06.01
6.	Mandua	2753	10.99	747	01.30
	Total cereals	21951	87.61	35903	62.54
7.	Pulses	1405	05.61	773	01.35
8.	<b>Total foodgrains</b>	22641	90.36	37391	65.14
9.	Oilseeds	663	02.65	3344	05.83
10.	Sugarcane	-		6565	11.43
11.	Potato	1470	05.87	367	00.64
12.	Kharif fodder	-		702	01.22
13.	Rabi fodder	-		678	01.18
14.	Zaid fodder	-		459	00.80
15.	Other	282	01.13	7899	13.76
	<b>Total</b>	25056	100.00	57405	100.00

Source: Statistical Bulletin, Nainital district, Uttarakhand, 2001

### 3.2.10 Average production and productivity

Average yield of 633.04 quintals per hectare for sugarcane, one of the most important crop besides rice and wheat, was observed in 1999-2000 (Table 3.2.7). Among cereals, the productivity of paddy and wheat was almost same being 24.33 and 24.34 quintals per hectares respectively. Pea among pulses has highest production and productivity both. Among oilseeds sunflower was having highest productivity viz. 13.02 quintals per hectare while the production was

maximum in case of lahi. Per capita production of cereals and pulses was 174.80 kg and 2.43 kg respectively in 1999-2000.

**Table 3.2.7: Average production and yields of selected crops in Nainital district, Uttarakhand (1999-2000)**

S.No	Crops	Production (metric tonnes)	Average yield (Quintals per hectare)
1.	Paddy	37600	24.33
2.	Wheat	78315	24.34
3.	Barley	1054	26.66
4.	Mandua	4741	13.55
5.	Jowar		11.71
6.	Maize	10792	13.56
7.	Sugarcane	415591	633.04
8.	Potato	41399	225.36
9.	Haldi	3	15.59
10.	Urd	257	04.87
11.	Massor	520	08.18
12.	Gram	448	09.72
13.	Pea	620	13.84
14.	Arhar	11	07.48
15.	Moong Kharif	1	05.00
16.	Moong Zaid		05.41
17.	Lahi	1890	10.04
18.	Til	8	01.51
19.	Groundnut	4	03.51
20.	Sunflower	1	13.02
21.	Soybean	1585	07.69

Source: Statistical Bulletin, Nainital district, Uttarakhand, 2001

### 3.2.11 Livestock

Table 3.2.8 presents the category wise distribution of the livestock population in district Nainital during 1999-2000

Table reveals that the total livestock population in the plains of district was estimated at about two lakh sixty six thousand. During the year 1999-2000, there were 138988 cattle, 2228 sheep, 28409 goats and 95660 poultry birds.

Table further indicates that in the total livestock population of the district, cattle accounted for 52.10 per cent. Poultry and goats accounted for 35.86 and 10.65 per cent respectively of the total livestock population.

**Table 3.2.8 : Distribution of livestock population in Nainital district, Uttarakhand (1997-98)**

S.No	Livestock	Hills		Plains	
		Population	Percentage	Population	Percentage
A.	<b>Cattle</b>				
	Adult male	24328	17.70	27198	10.19
	Cross breeds	7	00.01	291	00.11
	Adult female	34907	25.40	61652	23.21
	Cross breeds	24	00.02	1885	00.71
	Young stock	33152	24.12	46564	17.45
	Crossbre ds	38	00.03	1398	00.52
	<b>Total cattle</b>	<b>92456</b>	<b>67.28</b>	<b>138988</b>	<b>52.10</b>
B.	<b>Other animals</b>				
	Sheep Desi	72	00.05	996	00.37
	Sheep cross breeds	-		1232	00.46
	Goats	32262	23.48	28409	10.65
	Horses	2171	01.58	1268	00.48
	Pigs	-		226	00.08
	Poultry	10467	07.62	95660	35.86
	Total other animals	44972	32.72	127791	47.90
	<b>Total Livestock Population</b>	<b>137428</b>	<b>100.00</b>	<b>266779</b>	<b>100.00</b>

Source: Statistical Bulletin, Nainital district, Uttarakhand, 2001

## **MATERIALS AND METHODS**

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This chapter describes the procedure followed to fulfil the objectives of the study. The chapter is divided into three sections. Section one deals with the sampling design used to select the village development circles and farmers. Section two is concerned with the type of data collected and methods used for collection of the data. The analytical tools used to accomplish the objectives of the study have been discussed in section three.

### **4.1 Sampling design**

#### **4.1.1 Selection of study area**

The plain portion of Kumaon region was selected purposively, as there is wide scope for growing fast growing multipurpose trees in this area due to the well developed plywood, match and paper industries around the vicinity of this area.

#### **4.1.2 Selection of blocks, village development circles and farmers**

Plains of Kumaon region comprise the district Udham Singh Nagar, part of Nainital and very small portion of Champawat district. Therefore, Udham Singh Nagar and Nainital districts were selected as representative districts of Tarai and Bhabhar zone of the plains of Kumaon region.

#### **Selection of blocks and V.D.C.**

One block from each district\* was selected randomly. These blocks were

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\*In Nainital district selection was made among the blocks forming plains of Nainital i.e. Ramnagar, Haldwani and Kotabagh.

Rudrapur from U.S. Nagar and Haldwani from Nainital. A list of all village development circles was obtained for each block and the three sample village development circles (V.D.C.) were selected randomly from each block. In this way three V.D.C. were selected from Rudrapur block and four\*\* V.D.C. were selected from Haldwani block.

### Construction of age groups of agroforestry trees

A list of farmers of the selected V.D.Cs adopting agroforestry\*\*\* as a component in their farming systems was made separately for each block. The number of farmers adopting agroforestry in each selected V.D.C. is given below:

Block	Selected V.D.C.	Total farmers adopting agroforestry	Farmers adopting poplar	Farmers adopting Eucalyptus
Rudrapur	Bhurarani	130	130	-
	Kiratpur	198	191	7
	Lalpur	311	290	21
Haldwani	Halduchaur Dina	33	16	17
	Rampur Lamachaur	48	18	30
	Kishenpur Sakuia	9	9	-
	Haripur Bachhi	17	14	3

Eucalyptus and poplar were the only quick growing trees significantly adopted by the farmers of the study area. From the above mentioned list of farmers, groups were made according to the age of the tree. For poplar these

\*\* Due to insufficient number of farmers one village development circle was added to Haldwani block which had been selected randomly from the list of remaining village development circles of Haldwani block.

\*\*\*Only quick growing trees were considered for the present study.

age groups were 1<sup>st</sup> year, 2<sup>nd</sup> year, 3<sup>rd</sup> year, 4<sup>th</sup> year, 5<sup>th</sup> year, 6<sup>th</sup> year and > 6<sup>th</sup> year. There were no farmers available having Eucalyptus of 1<sup>st</sup> year, 2<sup>nd</sup> year, 3<sup>rd</sup> year and 4<sup>th</sup> year. Even for fifth year there were only two farmers. Hence it was not feasible to take Eucalyptus as the agroforestry component for the present study. Due to this limitation, final sample included only the farmers who were growing poplar as agroforestry component.

### Selection of farmers

Fifteen percent of the total farmers in each age group, were selected randomly, subject to a minimum of five in each age group. However due to insufficient number of farmers in Haldwani block only the minimum required number of five farmers could be selected there from. If number of farmers having trees of any specific age was less than five, then all the farmers have been selected for study as in the case of age group of three year where only four farmers were available. Final sample consisted 15 farmers from first year group, 18 farmers from second year group 12 farmers from third year group, 17 farmers from fourth year group, 20 farmers from fifth year group, 24 farmers from sixth year group and 17 farmers from seventh year group, making a total sample of 123 farmers. The total number of farmers in each tree age group and number of selected farmers in each tree age group (figures in parentheses) is given below :

Tree age group \ Block	1 <sup>st</sup> year	2 <sup>nd</sup> year	3 <sup>rd</sup> year	4 <sup>th</sup> year	5 <sup>th</sup> year	6 <sup>th</sup> year	>6 <sup>th</sup> year
Rudrapur	67(10)	93(13)	55(8)	83(12)	101(15)	128(19)	84(12)
Haldwani	6(5)	5(5)	4(4)	5(5)	22(5)	6(5)	8(5)
Total	73(15)	98(18)	59(12)	88(17)	123(20)	134(24)	92(17)

## **4.2 Collection of data**

The required information to achieve the objectives of the study was collected from primary as well as secondary sources.

The detailed information regarding family size, employment, source of income and income level as derived from crops and other on-farm enterprises, input-output coefficients, resource requirements, level of pre-determined activities, etc. was obtained from the sample farmers through personal interviews with the help of pretested schedules specially prepared for this purpose. The data pertains to the agricultural year 2002-2003.

The data from secondary sources was collected through personal visits of district offices, block offices, tehsil, and department of Agroforestry and Animal Sciences of the G.B.P.U.A.&T., Pantnagar.

## **4.3 Analytical tools**

This section is further divided into five parts describing the methodological details separately for each objective.

### **4.3.1 Identification of major farming systems involving agroforestry**

Of the total selected farmers if ten percent or more farmers were adopting a particular type of farming system, that farming system was treated as important one and selected for the study.

### **4.3.2 Economic analysis of selected farming systems**

A stream of gross costs, gross returns and net returns for each activity, included in farming system, were worked out.

In order to examine the profitability of poplar the stream of average gross costs and average gross returns from poplar raising either with crop rotations or without crop rotation (in case of boundary poplar) was prepared for the entire life of the poplar i.e. upto harvesting year at 2002-03 prices. The annual average gross costs and annual average gross returns were computed as follows:

$$(i) \text{ Annual average gross cost} = \frac{\sum_{i=1}^7 \text{Stream of average gross cost}}{7}$$

$$(ii) \text{ Annual average gross returns} = \frac{\sum_{i=1}^7 \text{Stream of average gross returns}}{7}$$

[i = age of poplar tree]

#### 4.3.3 Resource use efficiency of different farming systems

To examine the resource use efficiency in the selected farming systems, Cobb-Douglas type of production functions were fitted separately for each farming system. The form of this production function was as follows:

$$y = a X_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} X_6^{b_6} X_7^{b_7} X_8^{b_8}$$

This can be written in log linear form as :

$$\begin{aligned} \text{Log } Y &= \log_a + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4 \\ &+ b_5 \log X_5 + b_6 \log X_6 + b_7 \log X_7 + b_8 \log X_8. \end{aligned}$$

Where,

Y = gross returns per hectare (Rs)

X<sub>1</sub> = per hectare human labour use (man days)

X<sub>2</sub> = per hectare tractor power use (hours)

- $X_3$  = per hectare irrigation applied (number)
- $X_4$  = per hectare use of urea (kg)
- $X_5$  = per hectare use of DAP (kg)
- $X_6$  = per hectare seed material cost (Rs.)
- $X_7$  = per hectare cost of plant protection chemicals, seed treatment material and other miscellaneous materials (Rs.)
- $X_8^*$  = number of milch animals per farm

### **Testing of multicollinearity**

Before fitting the Cobb-Douglas function, zero-order correlation matrices were worked out for selected farming systems to examine the multicollinearity among the independent variables. The correlation coefficient ( $r$ )  $> 0.7$  between any two independent variables was considered as indication for the presence of multicollinearity.

### **Estimation of resource use efficiency**

The resource use efficiency of different inputs in different selected farming systems was examined using the criterion of comparison of marginal value productivity of different inputs with their acquisition costs (marginal factor costs). A resource or input was considered to be used most effectively whose MVP was sufficient to off set its cost.

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\*This independent variable was included for the farming systems having livestock enterprise.

## Estimation of MVP

The marginal value product of each input was calculated as follows:

$$MVP_{xi} = AVP_{xi} \cdot b_i$$

and 
$$AVP_{xi} = \frac{\bar{Y}}{\bar{X}_i}$$

Where,

$AVP_{xi}$  = Average value product of  $i^{\text{th}}$  input

$b_i$  = Elasticity of production of  $i^{\text{th}}$  input

$\bar{Y}$  = Geometric mean of gross returns

$\bar{X}_i$  = Geometric mean of gross  $i^{\text{th}}$  input

The marginal value products of different inputs were compared as follows:

$$\frac{MVP_{xi} < 1}{MFC_{xi} > 1}$$

- if the ratio is less than one than the resource is over utilized.
- If the ratio is equal to unity, the resource is efficiently utilized.
- If the ratio is greater than one then the resource is under utilized.

### 4.3.4 Development of optimum plans for different farming systems

Linear programming technique was used to work out the maximum attainable returns, by the optimum allocation of various resources for each selected farming system. Optimum allocation of various resources was defined as that which, given the physical, technical and resource conditions, shows the activities to be undertaken and how much of each resource to allocate to each activity so that net returns are maximized on an annual basis.

The mathematical formulation of the linear programming model used to maximize returns over variable costs and examine the effect on cropping pattern, number of livestock maintained, level of income and employment; is as follows :

$$\text{Maximize } Z = \sum_{j=1}^n C_{jFL} X_{jFL}$$

Subject to:

$$\sum_{j=1}^n a_{ijFL} X_{jFL} \begin{matrix} \leq \\ > \end{matrix} b_{iFL}$$

For ;

$j = 1, 2, \dots, n$

$i = 1, 2, \dots, m$

$L = 1, 2, 3, 4$

and

$X_{jFL} \geq 0$

Where,

$Z$  = net returns over variable cost

$C_{jFL}$  = net returns over variable cost per unit of  $j^{\text{th}}$  activity in  $L^{\text{th}}$  farming system.

$X_{jFL}$  = level of  $j^{\text{th}}$  activity in  $L^{\text{th}}$  farming system.

$FL$  = farming system

$b_{iFL}$  = supply level of  $i^{\text{th}}$  resource in  $L^{\text{th}}$  farming system

$a_{ijFL}$  = requirement of  $i^{\text{th}}$  resource per unit of  $j^{\text{th}}$  activity in  $L^{\text{th}}$  farming system

### **Objective function of the model**

The objective of the model was set to maximize net returns over variable costs separately for each farming system. The returns over variable costs were calculated for different annual crop rotations, agroforestry trees and livestock activities. These net returns over variable costs were worked out without deducting the cost of hired labour and borrowed capital from the gross returns. These costs were incorporated separately in the objective function as the  $C_j$  coefficient with negative sign.

### **Real activities**

#### **a) Crop and fodder activities**

All the important annual crop rotations followed in different farming systems were taken as real activities in the model. The important crop rotations followed in the study area were paddy (non basmati)- wheat, paddy (basmati)-wheat-summer paddy, sugarcane planted, sugarcane ratoon-wheat, maize+jowar-berseem, maize+jai-berseem, paddy-lahi-wheat, paddy-pea, paddy-lahi-sunflower, paddy-wheat-vegetable etc. The by-products of crops were generated by the crop activities and used as fodder by the livestock in the model. However, to fulfill the additional requirement of fodder, green fodder (kharif and rabi) and dry fodder purchase activities were incorporated in the model in different farming systems.

#### **b) Poplar activities**

The main poplar activities were poplar in boundary and poplar in block.

**c) Livestock activities**

The livestock activities considered in the model were milch animals (cows and buffaloes) and draft animals (bullocks).

**d) Labour hiring activity**

Provision was made for labour hiring activities in the model throughout the year, as labour availability was not observed a constraint in the study area.

**e) Cash borrowing activity**

Borrowing activities for cash in kharif and rabi season for different farming systems were introduced in the model with a limit set by the banks for the average size of the farm of the study area.

### **Resource constraints**

The different optimal plans were developed under existing constraints and resource supply. The important constraints are described below in brief :

**a) Land constraint**

The entire land available for cultivation with the farmers was considered as the supply level of the land restrictions.

**b) Human labour constraint**

Human labour was divided into two parts i.e. family labour and hired labour. Family labour restriction consisted of the seasonal supply of human labour in terms of male equivalent days on the basis of information recorded with respect to availability of family labour in a year. There was no problem of hired labour in the study area. The supply level of hired labour was put to zero and labour hiring activity was incorporated in the model.

**c) Working capital restriction**

Working capital restriction was put for kharif and rabi seasons separately for different farming systems. The use of cash for the purchase of seed, fertilizers, payment of irrigation charges, expenditure on plant protection chemicals, tractor hiring, feed and maintenance of livestock etc. in kharif and rabi seasons was taken as supply level of cash in respective season. Cash borrowing activities for kharif and rabi seasons were introduced in the model. The interest rate was taken as 10 percent per annum i.e. 5 per cent for kharif and 5 percent for rabi. The cost of borrowed funds i.e. interest rate was put in objective function with negative sign. Similarly, the cost of casual labour was put in the objective function with negative sign. In this way, labour can be hired upto a point where its marginal value productivity (MVP) was equal to the wage rate.

**d) Restriction on number of livestock**

While optimizing farming systems the number of milch animals were restricted to minimum and maximum number of livestock maintained on a farm.

**e) Supply of fodder**

Green fodder was obtained from fodder crops and sugarcane top during kharif and rabi season. Similarly dry fodder was obtained from the crops like wheat and paddy as by product and it was provided in the model for use by the livestock. The provision of green fodder and dry fodder purchase activity was made in the model. The supply level of these activities was put to zero in the model.

**f) Lower and upper area restrictions for different crop rotations**

The managerial constraints i.e. the upper and lower restrictions on the area under various crop rotations followed on the sample farms were put in different model in order to make sure that optimal plan in a particular farming system do not deviate so much that it will cross the adjustable limits of the farmers. These limits were fixed on the basis of needs and preferences of the sample farmers.

**Technological matrix**

Two sets of informations viz., input coefficients and output coefficients are important to develop a technological matrix.

**(a) Input coefficients**

The average requirements for the limiting inputs were calculated for different annual crop rotations and livestock activities.

**(b) Output coefficients**

The returns over variable cost per hectare of a crop rotation activity, poplar activity and per milch animal were obtained by deducting the respective variable cost per unit from gross returns per unit.

**4.3.5 Constraints in adoption of agroforestry**

To examine the level and extent of problems faced by farmers in growing, maintaining and marketing of poplar, descriptive statistics was used. Simple averages and percentages of the responses of farmers to various questions related to poplar adoption, were calculated. These questions were asked to farmers during the course of survey.

## RESULTS AND DISCUSSION

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The empirical findings of the present study are presented in five major sections. The section one has been devoted to the salient features of the identified farming systems involving poplar, adopted by the sample farmers of the study area. Second section discusses the costs and returns of different activities involved in different farming systems identified. Resource use efficiency examined for different farming systems is discussed in section three. Optimum plans derived for different farming systems have been discussed in fourth section. The constraints faced by the farmers in growing and marketing of poplar are presented in section five.

### 5.1 Important farming systems

The farming systems adopted by the sample farmers are presented in

Table 5.1

**Table 5.1 Important farming systems**

Farming system	No. of farmers adopting the farming system
Crop + poplar in block	14(11.29%)
Crop + poplar in boundary	20(16.13%)
Crop + poplar in boundary + livestock	36(29.00%)
Crop + poplar in block + livestock	49(39.52%)

Figures in parentheses are percentage to total number of sample farmers

Table 5.1 reveals that only four types of farming systems were followed by more than ten per cent farmers. It is evident from the table that 11.29 per

cent of the total sample farmers were growing poplar as block plantation with intercrops. Other crop activities were also taken in this type of farming system. 16.13 per cent of the total sample farmers were raising poplar in the boundary of their farms. They were also taking crop enterprises other than the poplar. 29 per cent of the total sample farmers were raising livestock (cows, bullocks) other than the poplar in boundary and crop enterprises. Maximum number of farmers i.e. 39.52% of the total sample farmers were taking crop activities, poplar as block plantation and livestock activities on their farms.

The general information regarding resource structure, cropping pattern, level of employment of these farming systems is presented in the following subsections.

### 5.1.1 Average size of farm holdings in different farming systems

The average size of farm holdings varied from one farming system to other. The size of land holding was largest (4.02 hectare) in crop + poplar in block + livestock farming system. It was smallest (2.60 ha) in crop + poplar in boundary farming system as depicted in Table 5.1.1.

**Table 5.1.1 : Average size of farm holdings in various farming systems (hectare)**

Farming system	Owned land	Leased in land	Leased out land	Total available land
Crop + poplar in block	3.53	1.36	0.05	4.84
Crop + poplar in boundary	2.60	0.17	0.07	2.70
Crop + poplar in boundary + livestock	3.61	0.78	0.35	4.04
Crop + poplar in block + livestock	4.02	1.18	-	5.20

100 per cent area was irrigated in all the farming systems. The major sources of irrigation were private tubewells, pumpsets and state tubewells in Rudrapur block and state tubewells and canals in Haldwani block. All the sample farmers in Rudrapur block had their own sources of irrigation i.e. diesel pumps and tubewells.

### 5.1.2 Availability of human labour in different farming systems

Family size and family working force varied between farming systems (Table 5.1.2). The working force consisted of male and female only. The participation of child labour in farm activities was found to be quite insignificant as majority of them were school going. Even the female workers were engaged in only the execution of some of the minor agricultural operations and livestock raising activities. Thus the working force was mainly dominated by the male workers in respect of number of male workers and mandays availability. For the purpose of working out the man days employment, the employment days of female workers were converted into male equivalent days treating female work day equal to 0.75 male work day.

**Table 5.1.2 : Availability of human labour in different farming systems (per farm)**

Particulars	Crop + poplar in block	Crop + poplar in boundary	Crop + poplar in boundary + livestock	Crop + poplar in block + livestock
1. Total family member	8.1	6.79	6.16	8.17
a) Male	3.00	2.58	3.10	2.36
b) Female	3.19	2.25	1.87	3.88
c) Children	1.91	1.96	1.19	1.93
2. Number of family members available for on farm work (male equivalent)	2.18	1.96	2.28	3.12
3. Mandays available per family per month for farm work	45	40	47	64

The number of family members ranged between 6.16 in crop + poplar in boundary + livestock farming system to 8.17 in crop + poplar in block + livestock farming system. The average working force ranged between 1.96 in crop + poplar in boundary farming system to 3.12 in crop + poplar in block + livestock farming system. Total mandays available per family per month for farm works varied from 40 in crop + poplar in boundary farming system to 64 in crop + poplar in block + livestock farming system.

Based on foregoing discussion it was observed that larger size of working force was observed in the farming system having livestock. Further the farmers having larger average family size i.e. 8.17 and 8.1 were growing poplar as block plantation.

### **5.1.3 Capital availability in different farming systems**

The Table 5.1.3 shows the capital investments comprising of farm implements, machinery and cattleshed etc., draft animals, milch animals on farms following different systems. Highest total investment of Rs.229584.10 was made in the crop + poplar in block + livestock farming system. Investment on livestock with respect to total investment was higher in crop + poplar in boundary + livestock farming system than that in crop + poplar in block + livestock farming system. The total investment on capital resource was lowest in crop + poplar in boundary farming system.

**Table 5.1.3 : Capital availability in different farming systems (per farm in Rs.)**

Particulars	Crop + poplar in block	Crop + poplar in boundary	Crop + poplar in boundary + livestock	Crop + poplar in block + livestock
1. Fixed assets*	151378.95 (100)	138107.70 (100)	119335.87 (77.96)	201345.10 (87.69)
2. Draft animals	-	-	12250 (8.00)	-
3. Milch animals	-	-	21482(14.03)	28239(12.30)
Total	151378.95 (100)	138107.70 (100)	153067.87	229584.10

Figures in parentheses shows the per centage of the total investment.

\* Fixed assets are farm machinery, implements, cattleshed, farm building etc.

#### 5.1.4 Cropping pattern

The cropping pattern of the sample farms for different farming systems for the year 2002-03 is presented in Table 5.1.4.

##### 5.1.4a Crop + poplar in block

Table 5.1.4 shows that paddy, sugarcane and wheat were the main crops which respectively occupied 18.84 per cent, 12.56 per cent and 12.82 per cent of the total cropped area. Summer paddy was the crop taken in Zaid season and it occupied 6.28 per cent of the total cropped area. Poplar in block enterprise was consuming 22.86 per cent of the total cropped area.

##### 5.1.4b Crop + poplar in boundary

In the crop + poplar in boundary farming system poplar was raised on the boundary of 2.12 hectare area of the total of 2.70 hectare. Major crops in kharif, rabi and zaid were paddy, wheat and pea respectively. Wheat was followed by lahi and pea as they occupied 17.69 per cent, 16.92 per cent and 14.62 per cent of the total cropped area, respectively.

Table 5.1.4 : Cropping pattern on sample farms (area in hectare)

Particular	Crop+ poplar in block	Percentage to total cropped area	Crop+ poplar in boundary	Percentage to total cropped area	Crop +poplar in boundary + livestock	Percentage to total cropped area	Crop + poplar in block + livestock	Percentage to total cropped area
Average area	4.84		2.70		4.04		5.20	
Average area in poplar	1.82	22.86	2.12		3.72		1.58	17.10
<b>Major crops in kharif</b>								
Paddy (basmati)	0.50	6.28	0.60	9.23	0.42	5.05	0.59	6.39
Paddy (non basmati)	1.00	12.56	1.10	16.92	1.58	18.99	1.05	11.36
Sugarcane	1.00	12.56	0.60	9.23	1.56	18.75	0.90	9.74
Ratoon	0.52	6.54	0.40	6.15	-	-	0.73	7.90
Fodder	-	-	-	-	0.48	5.7	0.35	3.79
<b>Major crops in rabi</b>								
Wheat	1.02	12.82	1.15	17.69	1.58	18.99	0.73	7.90
Potato	-	-	-	0.00	-	-	0.73	7.90
Pea	0.40	5.03	0.95	14.62	0.42	5.05	0.91	9.85
Sugarcane planted	1.00	12.56	0.60	9.23	1.56	18.75	0.90	9.74
Sugarcane ratoon	-	-	-	-	-	-	-	-
Fodder	-	-	-	-	0.48	5.77	0.35	3.79
Lahi	0.60	7.54	1.10	16.92	-	-	0.73	7.90
Sunflower	0.60	7.54	-	-	-	-	-	-
<b>Major crops in zaid</b>								
Paddy	0.50	6.28	0.60	9.23	-	-	0.59	6.39
Vegetables	-	-	-	-	1.38	16.59	-	-
Tomato	-	-	-	-	0.42	5.05	-	-
Total cropped area	7.96	100.00	6.50	100.00	8.32	100.00	9.24	100.00
Cropping intensity		152.07%		240.745%		205.94%		190.91%

#### **5.1.4c Crop + poplar in boundary + livestock**

In this farming system again paddy, wheat and sugarcane emerged as major crops which occupied 24.04 per cent, 18.99 per cent and 18.75 per cent of the total cropped area, respectively. Mainly vegetables were grown in zaid season. They occupied 16.59 per cent of the total cropped area. Poplar was surrounding the boundary of 3.72 hectare land.

#### **5.1.4d Crop + poplar in block + livestock**

Poplar was grown as block plantation only on the 1.58 hectare of the total area of 5.20 hectare. Paddy was the important crop in kharif followed by sugarcane. In rabi season maximum area was under pea followed by and wheat, potato and lahi. Lahi. Summer paddy was raised in zaid season and it occupied 6.39 per cent of the total cropped area.

Table 5.1.4 also indicates that the cropping intensity was maximum in the farming system of crop + poplar in boundary i.e. 240.74 per cent. It was minimum in crop + poplar in block farming.

### **5.2 Economics of different farming systems**

The costs and returns examined for different activities in different farming systems are described as follows :

#### **5.2.1 Crop + poplar in block farming systems**

##### **5.2.1a Costs and returns from various crop enterprises**

Average net returns over variable costs and net returns over total costs per hectare were computed for each activity taken by the farmers.

Poplar was being raised as block plantation with the intercrops as follows :

First year	-	Sugarcane planted
Second year	-	Sugarcane ratoon
Third year	-	Fallow – Wheat
Fourth year	-	Fallow – Wheat
Fifth year	-	Fallow – Wheat
Sixth year	-	Fallow – Wheat
Seventh year	-	Fallow

The average costs and returns from poplar with the intercrops were worked out for each year and then annual average costs and returns were calculated as described in the fourth chapter (Materials and Methods). The estimates of these costs and returns are given in Table 5.2.1a. Farmers were also taking crop enterprises other than the intercrops with poplar. The costs and returns estimates of these crops per hectare are also presented in the Table 5.2.1a.

Table 5.2.1a shows that poplar was generating second best net returns both over variable cost and total cost after sugarcane. Cost of production of sugarcane was also higher than that of poplar in block. It was Rs. 55076 per hectare while that of poplar was Rs. 50941. Lowest variable cost of production was incurred in the production of lahi which was Rs. 7003. But the gross returns per hectare were lowest as well for lahi. Sugarcane ratoon emerged out to be the most remunerative crop as it was giving highest returns on per rupee of investment (Rs.5.3). After sugarcane ratoon highest returns on per rupee of

**Table 5.2.1a : Costs and returns (per ha) of different activities in crop + poplar in block farming system (Rs.)**

Activities	Labour cost (hired)	Machinery hiring cost	Seed cost	Fertilizer cost	P.P. Chem. Cost	Miscellaneous	Total variable cost	Gross returns	Returns per rupee investment	Net returns over variable cost	Fixed costs	Net returns over total cost
Poplar in block	3953	3402	4120	3383	1130	1010	16998	56226	3.31	39228	23943	15285
Paddy (basmati)	2700	3450	263	2150	1500	2000	12063	37700	3.13	25637	22148	3489
Paddy (non-basmati)	2166	3817	161	2645	150	2610	11549	30310	2.62	18761	19222	-461
Sugarcane planted	10863	3672	10000	3690	478	4851	33554	79200	2.36	45646	21522	24124
Sugarcane ratoon	4751	836	-	750	4175	1000	7755	41144	5.31	33390	20913	12477
Wheat	1400	3814	1158	2135	57	1000	9564	24142	2.52	14578	19213	-4635
Pea	2995	5063	3325	2050	100	700	14233	26630	1.87	12397	20697	-8300
Lahi	1140	2613	525	2275	-	450	7003	18000	2.57	10997	19886	-8889
Sunflower	2535	3375	1286	4200	100	750	12246	19500	1.59	7254	18873	-11619
Summer paddy	2081	3942	205	2668	500	2990	12386	31459	2.54	19073	19184	-111

investment were drawn by poplar (Rs. 3.31). Only poplar, paddy (basmati), sugarcane planted and sugarcane ratoon were able to recover their fixed cost of production. Paddy (non-basmati), wheat, pea, summer paddy, lahi and sunflower were giving negative net returns over total costs. The major part of fixed costs were composed of rental value of land that was Rs.18750 per hectare. Rest part of the fixed cost consisted land revenue, depreciation on equipments, machinery and other assets and imputed value of family labour. Family labour cost was imputed with the help of prevailing average wage rates in the study area. With respect to net returns over variable costs all the activities emerged out to be profitable in this farming system.

### 5.2.1(b) Income and employment generation

Crop rotations wise net income (net returns over variable costs) per farm in crop + poplar in block farming system are given in Table 5.2.1(b).

**Table 5.2.1b: Costs, returns and human labour employment in crop + poplar in block farming system**

Activity/Crop-rotation	Area (ha)	Total variable costs (Rs)	Gross returns (Rs)	Per farm	
				Net returns over variable costs (Rs)	Human labour employment (days)
Paddy (B)-wheat -summer paddy	0.50	17007	46651	29645 (14.37)	118
Paddy (NB)-lahi-sunflower	0.60	18479	40686	22207 (10.76)	120
Paddy (Non basmati)-Pea	0.40	103.13	22776	12463 (6.04)	104
Sugarcane planted	1.00	33554	79200	45646 (22.13)	218
Sugarcane ratoon-wheat	0.52	9005	33949	24944 (12.09)	123
Poplar in block	1.82	30936	102331	71395 (34.60)	86
Total	4.84	119294	325593	206300 (100)	769
Per hectare	1.00	24648	67271	42624	159

Figures in parentheses are percentage to total income  
B – Basmati, NB – Non basmati

Table 5.2.1b reveals that per farm maximum income was generated (34.60 per cent) from poplar on account of the maximum area (1.82 hectare)

allotted to the block plantation. Farmers were incurring highest variable cost on sugarcane planted i.e. Rs. 33554. Per annum estimated variable cost of poplar was Rs. 30936 for 1.82 hectare. Farmers were investing minimum variable cost on sugarcane ratoon- wheat rotation which was giving 12.09 per cent of the total income per farm. Among the rotations of paddy, maximum area was allotted to paddy-lahi-sunflower rotation i.e. 0.60 hectare but the income was higher in case of paddy-wheat-summer paddy rotation. This was on account of the higher net returns from paddy (basmati) (Table 5.2.1a). The total human labour employed per farm was 769 days. Sugarcane planted was generating maximum net returns per farm among crop enterprises (22.13 per cent). It was also giving maximum employment i.e. 218 labour days. As the activities in this farming system were generating positive net returns over variable cost, this farming system can be treated as financially feasible. Per hectare net returns over variable cost were Rs.42624 and per hectare employment generation was 159 labour days per annum in this farming system.

## **5.2.2 Crop + poplar in boundary farming system**

### **5.2.2a Costs and returns from various crop enterprises**

Poplar in the boundary of 1 hectare land was giving a gross returns of Rs. 6000 per year with a very insignificant expenditure of Rs.464. The net returns over variable cost from the poplar in boundary of one hectare thus were Rs.5536. Maximum net returns over variable costs were generated from sugarcane ratoon with poplar in boundary plantation. Minimum variable cost among crop enterprises were of lahi. If we closely compare the gross returns

**Table 5.2.2a : Costs and returns (per ha) of different activities in crop + poplar in boundary farming system (Rs.)**

Activities	Labour cost (hired)	Machinery hiring cost	Seed cost	Fertilizer cost	P.P. Chem. Cost	Miscellaneous	Total variable cost	Gross returns	Returns per rupee investment	Net returns over variable cost	Fixed costs	Net returns over total cost
Poplar in boundary	157	-	108	100	42	57	464	6000	12.9	5536	301	5235
Paddy (basmati)	3700	4575	300	1105	1345	1585	12610	24800	1.97	12190	19286	-7096
Paddy (PR 13) with boundary poplar	4925	5282	250	2000	675	2673	15805	27591	1.75	11786	19538	-7752
Sugarcane planted with boundary poplar	7455	4675	9263	2475	303	1300	25471	55125	2.16	29654	20705	8949
Sugarcane ratoon with boundary poplar	4040	1250	-	1925	1000	600	8815	35625	4.04	26810	21237	5573
Wheat with boundary poplar	1335	4367	1524	2164	1000	470	10860	20023	1.84	9163	19471	-10308
Pea	3775	3006	3600	2820	630	1400	15231	26124	1.72	10893	20431	-10138
Lahi with boundary poplar	1060	1607	355	1433	100	121	4676	15754	3.37	11078	20096	-9018
Summer paddy	3325	5375	250	2125	450	1620	13145	22758	1.73	9613	19426	-9813
Pea with boundary poplar	3900	2765	3600	2975	1000	1100	15340	24000	1.56	8660	20247	-11587

from different crops grown with poplar in boundary plantation with that of the gross returns of same crops without boundary plantation as in case of crop + poplar in block farming system (Table 5.2.1a), we observed that the gross returns were always higher in later case. This was because of the lower yield of these crops caused by the shadow of poplar in boundary plantation. If we add the per hectare gross returns of boundary poplar to gross returns of these crops the gap can be more or less compensated. Due to lower gross returns no crop except sugarcane planted and sugarcane ratoon was able to cover its fixed cost. Poplar in boundary plantation was incurring lower fixed cost as rental value of land was not added to this cost.

After poplar in boundary and sugarcane ratoon, lahi was giving maximum gross returns on per rupee of investment. Sugarcane ratoon was generating maximum net returns over variable costs after sugarcane planted crop. Sugarcane ratoon was incurring lesser variable cost than sugarcane planted because there was no seed cost involved in the cost of production of ratoon crop which made a significant part of the variable cost of sugarcane planted. Expenditure on labour, machinery and fertilizer was also lower in sugarcane ratoon in comparison with sugarcane planted. As net returns over variable cost for all the activities in this farming system were positive, these activities can be treated as profitable enterprises.

### 5.2.2b Income and employment generation per farm

The costs and returns and net income (net returns over variable costs) for each annual crop rotation per farm are presented in Table 5.2.2b. The human labour employed in each rotation is also given in the Table.

**Table 5.2.2b : Costs, returns and human labour employment in crop + poplar in boundary farming system**

Activity	Area (ha)	Total variable costs (Rs.)	Gross returns (Rs.)	Net returns over variable costs (Rs.)	Human labour employment (days)
Poplar in boundary	2.12	984	12720	11736 (11.90)	7.5
Paddy(B)-pea-summer paddy	0.60	24592	44209	19617 (19.90)	136
Paddy(NB)-lahi-wheat with boundary plantation	1.10	34475	69705	35230 (35.73)	171
Sugarcane planted with boundary plantation of poplar	0.60	15283	27075	17792 (18.05)	91
Sugarcane ratoon-wheat with boundary plantation	0.05	983	2782	1799 (1.82)	6.5
Sugarcane ratoon- pea with boundary plantation	0.35	8454	20869	12415 (12.59)	65
<b>Total</b>	<b>2.7</b>	<b>84771</b>	<b>177360</b>	<b>98589 (100)</b>	<b>477</b>
Per hectare	1.0	31397	65689	36514	177

Figures in parentheses are percentage to total income

B – Basmati, NB – Non basmati

The per farm net income over variable costs generated from the crop + poplar in boundary farming was Rs.98589 which was lower than the income generated from crop + poplar in block farming system i.e. Rs.206300. This was on account of the lesser area per farm in the former i.e. 2.7 hectare. Per hectare net income in this farming system was also lower than that of crop +

poplar in block farming system (Table 5.2.1b). This was mainly because of the higher per hectare paid out expenses i.e. Rs.31397 in crop + poplar in boundary farming system. The other reason was the reduction in yield of different crops which were grown in the field with boundary plantation of poplar. Per hectare employment was more i.e. 177 man days in comparison to 159 man days in case of crop + poplar in block. The explanation behind this lies in the greater allocation of farm area to pea and lahi in this farming system as these crops were engaging more labour.

The major contribution to the net income of crop + poplar in boundary farming was that of paddy-lahi-wheat crop rotation which was attending 1.10 hectare of the total farm area of 2.7 hectare.

Second best contribution was from paddy (basmati) – pea-summer paddy rotation (Rs.19617). It was contributing 19.90 per cent of the net farm income.

Sugarcane planted was raised on the same amount of area i.e. 0.60 ha as the rotation paddy-pea-summer paddy. But the net income was lower (Rs.17792) as compared to net income (Rs.19617) from the later. Reason behind this again was the reduction in yield of sugarcane due to boundary plantation and thereby reduction in gross returns. Otherwise variable costs incurred in sugarcane planted was lower than that of paddy-pea-summer paddy rotation.

### **5.2.3 Crop + poplar in boundary + livestock farming system**

#### **5.2.3a Costs and returns from various crop enterprises**

Table 5.2.3a reveals that poplar generated net returns over variable costs of Rs.4686 per hectare boundary, which were lower than the net returns over variable cost of poplar in one hectare boundary of crop + poplar in boundary farming system. Though gross returns were higher in this farming system. But the variable cost was much more due to greater expenditure of plant protection chemicals. The reason behind this was that the crop + poplar in boundary + livestock farming system had been mainly followed by farmers of Haldwani block and in this particular block problem of insect pest on poplar trees was severe. This resulted into higher expenditure on plant protection chemicals.

Sugarcane and vegetables were the only crops covering their total cost of production i.e. both variable costs and fixed cost. Yield of sugarcane was not affected much by the boundary plantation of poplar. This might be due to better management efficiency and efficient use of inputs. Fodder was not grown for commercial purpose. Cost of production of both kharif fodder and rabi fodder was lower comparative to other crops. Though gross returns from non-basmati paddy were higher than that of paddy basmati but net returns over variable costs were almost same for both as the variable cost for paddy non-basmati was much higher i.e. Rs.11453 than that for paddy basmati i.e. Rs.9011. Tomato and vegetables were the crops grown only in this farming system. Tomato did not generate very good results in year 2002-03 due to the glut of production in

Table 5.2.3a : Costs and returns (per ha) of different activities in crop + poplar in boundary + livestock farming system (Rs.)

Activities	Labour cost (hired)	Machinery hiring cost	Seed cost	Fertilizer cost	P.P. Chem. Cost	Miscellaneous	Total variable cost	Gross returns	Returns per rupee investment	Net returns over variable cost	Fixed costs	Net returns over total cost
Poplar in boundary	149	-	114	365	956	158	1742	6428	3.69	4686	291	4395
Paddy (basmati)	3308	3026	264	2014	179	220	9011	27560	3.06	18549	20217	-1668
Paddy (non-basmati (bound.))	3567	4055	379	2705+90	347	310	11453	31241	2.73	19788	20232	-444
Kharif fodder bound.	1043	2863	936	1742	-	311	6895	11713	1.70	4818	19411	-14593
Sugarcane bound.	9675	3665	8974	2915	208	1926	27363	63732	2.33	36369	21793	14576
Wheat + bound.	2126	2908	1215	2292	475	1372	10388	21090	2.03	10702	19729	-9027
Pea	2996	4889	3750	1711	1000	311	14657	27300	1.86	12643	20412	-7769
Rabi fodder bound.	838	3507	1199	998	230	170	6942	23998	3.46	17056	20124	-3068
Tomato	7125	6006	1900	3050	220	230	18531	16000	0.86	-2531	21299	-23830
Vegetable bound.	2000	2719	3500	2850	1000	840	12909	45000	3.49	32091	19515	12576

Haldwani block but otherwise it had generated good returns to farmers in the past.

### 5.2.3b Costs and returns from the milch animals

Farmers were taking livestock enterprises, alongwith the crops. The main livestock activities raised were cross-bred cow, desi cow and bullocks. The costs in rearing the cows and returns generated from them are presented in Table 5.2.3b.

**Table 5.2. 3.b : Costs and returns from livestock activities**

(Rs./animal)

Type of milch animal	Cross-bred cow	Indigenous cow
<b>Particulars</b>		
<b>Variable costs</b>		
Kharif green fodder cost	1050	980
Kharif dry fodder cost	560	675
Rabi green fodder cost	1200	1120
Rabi dry fodder cost	900	1000
Concentrate cost	7206	5320
Medicines and other expenditure	300	300
Total variable cost	11216	9395
<b>Fixed cost</b>		
Imputed value of family labour	4550	4550
Depreciation on equipments, cattleshed	86.46	86.46
Depreciation on animal	706	706
Total fixed cost	5342.46	5342.46
Total cost	16558.46	14736
Gross returns	33167	25950
Net returns over variable costs	21951	16555
Net returns over total cost	16608.54	11213

On an average two milch animals were maintained on a farm i.e. one cross bred cow and one Sahiwal cow. Table 5.2.3b shows that total cost incurred on cross bred cow was more than that of Sahiwal. The main part of the higher cost of cross bred cow was that of concentrates. More concentrates were required for the cross bred cow. Average gross return per annum by cross bred cow was significantly higher i.e. Rs.33167 than from Sahilwal which were Rs.25950 per year. Net returns over variable costs as well as over total cost per year were positive for both breeds. The major part of fixed cost was composed of the imputed value of family labour. Nearly 91 family labour days were employed per animal per year. Thus livestock enterprise emerged out to be a remunerative and employment generating activity for a farmer.

### **5.2.3c Income and employment generation per farm**

The net income and human labour employment generated on an average farm from different activities in crop + poplar in boundary + livestock farming system are presented in Table 5.2.3c.

Per hectare net income was quite high in comparison to the other two farming systems discussed earlier. But if we look at the net income per hectare from crop enterprises only, the net returns over variable costs were only slightly higher than the crop + polar in boundary farming system but they were lower than the per hectare net income in crop + poplar in block farming system. However, the inclusion of two milch animals significantly increased the net income per hectare. The price of dry fodder from paddy and wheat in the rotations paddy (basmati)-pea-tomato, paddy (Non-basmati) –wheat-vegetables

and paddy (Non-basmati) – wheat were not included in the gross returns of these crop rotations. Similarly price of sugarcane top were not included in the gross returns of sugarcane. At the same time prices of kharif and rabi green fodder produced (which included maize, jowar, jai and berseem) were not treated as gross returns. As all of these were not sold but used on farm for the milch animals and bullocks. Similarly prices of dry fodder and green fodder were not included in the variable costs of livestock activities as they were not the purchased items.

**Table 5.2.3c: Cost, returns and human labour employment in crop + poplar in boundary + livestock farming system**

Activity	Area (ha)/ No. of animal	Variable costs (Rs.)	Gross returns (Rs.)	Per farm	
				Net returns over variable costs (Rs.)	Human labour employment (days)
Paddy(B)-pea-tomato	0.42	17724	28285	10561 (5.31)	126
Paddy(NB)-wheat-vegetables with boundary poplar	1.38	47955	123146	75191 (37.81)	223
Paddy (NB)-wheat with boundary plantation	0.20	4368	8578	4210 (2.12)	23
Sugarcane planted with boundary poplar	1.56	42686	95397	52711 (26.50)	297
Kharif fodder-Rabi fodder	0.48	6642	-	-6642	27
Poplar in boundary	3.62	6306	23269	16963 (8.53)	12
Cross bred cow	1	7506	33167	25661 (12.90)	91
Sahiwal cow	1	5620	25950	20330 (10.22)	91
Bullocks	2	100	-	100	102
Total	4.04	138907	337792	198885 (100)	992
Per hectare returns	1.00	44335	128096	83761	459
Per hectare (from crop enterprises only)	1.00	31109	68979	37870	175

Among milch animals, cross bred cow was giving greater gross returns as well as net returns than the Sahiwal cow. The average milk yield of cross bred was higher than that of Sahiwal. The returns from bullocks were indirectly being generated from the crop enterprises. Highest contribution to total net income per farm was from the crop rotation paddy (non-basmati) – wheat-vegetables. It was 37.81 per cent of the total net income. Though sugarcane planted was engaging the highest area but it could not compete the aforesaid rotation. Both of the milch animals were contributing greater than ten per cent of the net income (net returns over variable costs per farm). Poplar contributed lesser to the total net income per farm in this farming system as compared to the previously discussed farming systems. Total annual human labour employment was 992 labour days per farm. The major portion of the employed family labour days was engaged in maintaining livestock enterprises. Among crop enterprises the per hectare per annum human labour days employed were only 175. It was slightly lower than the per hectare human labour days employed in crop + poplar in boundary farming system (Table 5.2.2b).

Overall this farming system emerged out to be more income and employment generating farming system as compared to others.

#### **5.2.4 Crop + poplar in block + livestock farming system**

##### **5.2.4a Costs and returns from different crop enterprises**

Poplar as block plantation was grown with different crop rotations in different years as follows :

**Table 5.2.4a : Costs and returns (per ha) of different activities in crop + poplar in block + livestock farming system (Rs.)**

Activities	Labour cost (hired)	Machinery hiring cost	Seed cost	Fertilizer cost	P.P. Chem. Cost	Miscellaneous	Total variable cost	Gross returns	Returns per rupee investment	Net returns over variable cost	Fixed costs	Net returns over total cost
Poplar in block	4174	3959	4022	3400	928	1496	17979	58391	3.25	40412	19947	20465
Paddy (basmati)	4336	2488	250	1905	350	368	9697	28250	2.91	18553	19443	-890
Paddy (non-basmati)	4322	3447	219	2403	250	355	10996	28350	2.58	17354	19436	-2082
Sugarcane planted	10654	4048	8633	3179	400	1300	28214	69598	2.47	41384	20507	20877
Sugarcane ratoon	3329	1717	-	1100	105	300	6551	35964	5.48	29413	19767	9646
Kharif fodder	575	1520	500	-	-	300	2895	12250	4.23	9355	19358	-10003
Wheat	2760	4217	1300	2414	200	600	11691	21504	1.84	9813	19149	-9336
Pea	2087	4520	3800	2166	-	350	12923	26500	2.05	13577	19951	-6374
Potato	4350	4050	12000	2700	350	2250	25700	52050	2.03	26350	20372	5978
Rabi fodder	600	1747	900	470	-	431	4148	28000	6.75	23852	19724	4128
Lahi	1122	2107	164	1133	400	-	5026	24357	4.85	19331	19709	-378
Summer paddy	4336	3488	217	2405	-	300	10746	36784	3.42	26038	19682	6356

First year	-	Sugarcane planted
Second year	-	Sugarcane ratoon - wheat
Third year	-	Jowar – wheat
Fourth year	-	Jowar – wheat
Fifth year	-	Wheat alone
Sixth year	-	Wheat alone
Seventh year	-	Fallow

Poplar as block plantation was generating gross returns of Rs.58391 per hectare. Sugarcane planted was the highest return generating crop. Gross returns from sugarcane planted were Rs.69598 per hectare. The net returns over variables cost from these two activities were very close to each other because of the higher variable cost in case of sugarcane planted production. Summer paddy was giving exceptionally higher returns (Rs.26038) as compared to paddy basmati (Rs.18553) and paddy non-basmati (Rs.17354) in this farming system. Farmers were also growing potatoes in this farming system. Potato was producing a gross income of Rs.52050 per hectare. Thus potato emerged out to be an important cash crop of this farming system. Potato was among the other crops which were covering their fixed costs. These crops were sugarcane planted, potato, sugarcane ratoon and summer paddy. Poplar was also covering the annual fixed cost incurred in its production. All the crops were generating positive net returns over variable costs and thus can be treated as profitable enterprises.

#### **5.2.4b Costs and returns from different livestock enterprises**

Farmers were rearing three type of milch animals in crop + poplar in block + livestock farming system. These were Sahiwal cow, Jersey cow and

Murrah buffalo. Maximum expenditure was incurred in rearing of Jersey cow but the total costs incurred were maximum in case of Murrah buffalo. It was Rs.19028 per buffalo (Table 5.2.4b). Buffalo was generating maximum gross as well as net returns. This was mainly because of the higher price received for buffalo milk (Rs.11-12/litre). Jersey cow was giving better returns than the Sahiwal cow because average annual milk yield of Jersey cow was higher than that of Sahiwal. Three of the milch animals were covering both the variable cost and fixed cost incurred in their raising. Therefore livestock enterprise was found to be a profitable enterprise for this farming system.

**Table 5.2.4b : Costs and returns from livestock activities**

Type of milch animal Particulars	(Rs./animal)		
	Indigenous cow (Sahiwal)	Cross-bred cow (Jersey)	Buffalow (Murrah)
<b>Variable cost</b>			
Kharif green fodder cost	980	840	1120
Rabi green fodder cost	1120	960	1280
Rabi dry fodder cost	1100	1100	1400
Concentrate cost	5846	8487	7380
Medicines and others	234	400	200
Total variable cost	10300	12724	12505
<b>Fixed cost</b>			
Imputed value of family labour	4360	4902	5123
Depreciation on equipment	166.67	166.67	5123
Depreciation on animals	848	-74	1233
Total fixed cost	5375	4994.7	6523
Total costs	15675	17719	19028
Gross returns	26340	30920	35040
Net returns over variable costs	16040	18196	22535
Net returns over total costs	10665	13201	16012

### 5.2.4c Income and employment generation per farm

Different crop rotations and livestock activities taken on an average farm in the crop + poplar in block + livestock farming system are presented in Table 5.2.4c alongwith their costs, returns and human employment generated by them.

**Table 5.2.4c : Costs, returns and human labour employment in crop + poplar in block + livestock farming system**

Activity	Area in ha/ No. of milch animal	Variable costs (Rs.)	Gross returns (Rs.)	Net returns over variable costs (Rs.)	Human labour days employment
Poplar in block	1.58	28407	92258	63851(22.93)	132
Paddy(B)-pea-summer paddy	0.59	19686	51791	32105(11.53)	129
Paddy (NB)-lahi-potato	0.73	30457	75157	44700(16.05)	152
Paddy(NB)-pea-fallow	0.32	7654	16981	9327(3.35)	44
Sugarcane planted	0.90	25393	60470	35077(12.60)	186
Sugarcane ratoon-wheat	0.73	13317	39434	26117(9.38)	86
Kharif fodder-rabi fodder	0.35	2465	-	-2465	11.5
Cow (Sahiwal)	1	6080	26340	20260(7.28)	87
Cow (cross-bred)	1	8887	30920	22033(7.91)	98
Buffalo (Murrah)	1	7580	35040	27460(9.86)	102
Total	5.20 ha 3 animal	149926	428391	278465(100)	1027.5
Per hectare (from crop enterprises only)	1.00	24496	64633	40137	142
Per hectare total		47043	156933	109890	429

Figures in parentheses are per centage to total income

B - Basmati, NB - Non-basmati

The returns from fodder crops and costs of milch animals were estimated as described for crop + poplar in boundary + livestock farming system.

Table 5.2.4c shows that total income per farm was maximum in this farming system. Net income per hectare was also higher than any other farming system. If we have a glance on net returns over variable cost per hectare from crop enterprises only we see that these were higher than crop +

poplar in boundary + livestock farming system and crop + poplar in boundary farming system. But these were slightly lower than the net income per hectare in crop + poplar in block farming system. Poplar in block was contributing 22.93 per cent of the total income per annum. Murrah buffalo was contributing maximum among milch animals (9.86 per cent). Among crop enterprises paddy (non-basmati)-lahi-potato crop rotation was contributing maximum to the total income (16.05 per cent). Sugarcane occupied maximum area among crop enterprises and generating 12.60 per cent of the total income.

This farming system generated an employment of 1027.5 human labour days per year. Per hectare employment from crop enterprises was only 142 labour days per year. Per hectare total employment generation was 429 human labour days.

Thus most profitable farming system was crop + poplar in block + livestock farming system. Poplar was an important income generating enterprise for all the farming systems. Poplar in block emerged out to be a significant employment generating activity as well. All the crop activities were giving positive net returns over variable costs except tomato.

In terms of net returns over variable cost per farm all the farming systems were financially viable.

### **5.3 Resource use efficiency in different farming systems**

#### **5.3.1 Regression results**

To estimate the marginal value products and resource use efficiency of farm inputs the Cobb Douglas type of functions were fitted separately for each

selected farming system. The results of the regression analysis are shown in Table 5.3.1.

**Table 5.3.1 : Cobb-Douglas production function estimates for different farming systems**

Sl. No.	Farming systems Particulars	Crop + poplar in block	Crop + poplar in boundary	Crop + poplar in boundary + livestock	Crop + poplar in block + livestock
1.	Number of observations	14	20	36	49
2.	Intercept	11.12904	10.7121	15.00794	8.004358
3.	Human labour days per ha	0.1434879** (0.047829)	0.2090985* (0.0822660)	-0.882*** (0.3029112)	0.9572 (0.944036)
4.	Tractor hour per ha	-0.208215 (0.2391743)	-0.1974516 (0.3104873)	0.2689* (0.14633)	0.211304* (0.1004920)
5.	Irrigation number	-0.2064017 (0.01427099)	0.215109** (0.1068365)	0.17565* (0.1139111)	0.054491** (0.028591)
6.	Urea in kg per ha	0.049941 (0.03784574)	-0.33675 (0.2760833)	0.055383 (0.1766030)	0.091805 (0.0765461)
7.	DAP in kg per ha	0.03605022** (0.01472188)	0.057058*** (0.016936)	0.131697** (0.0424682)	0.09112*** (0.01186832)
8.	Seed material costs per ha	0.132908* (0.0591743)	0.0885629*** (0.0205567)	0.082513* (0.039450)	0.050499* (0.029693)
9.	Plant protection chemicals costs per ha	-0.2188951 (0.307330)	0.036581 (0.28794)	0.030763 (0.0441316)	0.03549 (0.0501465)
10.	Number of milch animals per farm	-	-	0.596733*** (0.0776068)	0.750352*** (0.053104)
11.	R <sup>2</sup>	0.7583	0.83662	0.725365	0.8791

Figures in parentheses are the standard error of coefficient

- \*\*\* Significant at 1 per cent level
- \*\* Significant at 5 per cent level
- \* Significant at 10 per cent level.

Table 5.3.1 shows that the coefficients of multiple determination for all sets of production function were notably high. Which ranged from 0.725365 in the case of crop + poplar in boundary + livestock farming system to 0.879110 in crop + poplar in block + livestock farming system. Thus more than 72 per

cent of variation in gross returns at a farm was explained by the independent variables included in the model.

In crop + poplar in block farming system human labour, DAP and seed materials were the major factor responsible for increasing gross returns on a farm. These were significantly affecting gross returns at 5 per cent, 5 per cent and 10 per cent significance level, respectively. Tractor hours, number of irrigations and plant protection chemicals costs were showing over utilization as per unit increase of these variables was reducing gross returns. But their effect was not significant on gross returns. Quantity of urea was not affecting gross returns significantly but its effect was positive.

Number of irrigations, quantity of DAP and seed materials costs were the three variables which were affecting gross returns positively and significantly in rest of the three farming systems. Tractor hours were being used in the third stage of production in case of crop + poplar in boundary farming system. Similar was the case with quantity of urea. The reason behind this might be the smaller size of an average farm (2.7 hectare) in the aforesaid farming system in comparison to other farming systems.

The production elasticities of tractor hours were found to be positive and significant in crop + poplar in boundary + livestock farming system and crop + poplar in block + livestock farming system.

Human labour was highly over utilized in the crop + poplar in boundary + livestock farming system. One unit increase of human labour was causing decrease in gross returns significantly. This particular farming system was

mainly prevailing in the Haldwani block. Where the family labour was experiencing disguised unemployment.

The regression coefficients of number of milch animals were found to be positive and highly significant in both the farming systems having livestock enterprises.

Cost of plant protection chemicals was not affecting the gross farm income significantly in any of the farming systems. This was because there was great variation in the level of plant protection chemicals used from farm to farm in each farming system.

### **5.3.2 Estimation of economic efficiency**

The fitted production functions (Table 5.3.1) were used to test the efficiency of different farm inputs for different farming systems. Marginal value products and profitability ratios (MVP/MFC) were calculated\* at the geometric mean levels of various farm inputs and gross returns. The marginal factor cost (MFC) or opportunity cost of human labour used was the prevailing average wage rate in the study area, that of tractor hour was the average hiring rate per hour prevailing in the study area. M.F.C. of each irrigation per hectare was the estimated average cost per hectare per irrigation on an average farm. This cost differed in the farming systems having poplar in block with that of farming systems having poplar in boundary because of the fact that farming systems having poplar in boundary were mainly prevailing in Haldwani block and on an average farmers in this block were incurring more cost per irrigation

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\*Profitability ratios and MVP were calculated only for those independent variables which were found to be positively affecting gross returns.

as compared to the farmers in Rudrapur block, most of whom were having their private tubewells. Costs of per kilogram urea and DAP was imputed with the help of prevailing rates of these fertilizers in the study area. MFC for seed material and plant protection chemicals were Re 1.00 as these variables were measured in monetary terms, because of disparities in the crops and type of plant protection used per farm. Marginal factor cost per milch animal was the average of the operational cost incurred per milch animal.

The marginal value products and profitability ratios for the farm inputs which were affecting gross returns positively (Table 5.3.1) for each farming system are presented in Table 5.3.2.

Table 5.3.2 shows that productivity of human labour was highest in crop + poplar in block + livestock farming system. It was also high in crop + poplar in boundary farming system.

Productivity of tractor hours worked out to be high in crop + poplar in boundary + livestock farming system.

Contribution of one unit increase in irrigation to gross returns per hectare was highest in crop + poplar in boundary i.e. Rs.1443.82. Irrigation also contributed considerably to the gross returns of crop + poplar in boundary + livestock farming system. It was the main determinant of gross returns in crop + poplar in boundary farming system. Marginal value product of urea was highest in crop + poplar in block + livestock farming system. While the productivity of DAP was highest in crop + poplar in boundary + livestock farming system.

Table 5.3.2 : Resource use efficiency in different farming systems

Sl. No.	Resources	Human labour (man days per hectare)	Tractor power (hour) per hectare	Irrigation (number) per hectare	Urea (kg) per hectare	DAP (kg) per hectare	Seed material (Rs.) per hectare	Plant protection (Rs.) per hectare	Milch animals (number)	
1.	<b>Marginal value product (MVP) (Rs.)</b>									
	Crop + poplar in block	97.29	-	-	4.27	6.70	2.30	-	-	
	Crop + poplar in boundary	168.83	-	1443.82	-	14.54	1.44	3.05	-	
	Crop + poplar in boundary + livestock	-	597.84	1191.14	9.70	40.21	1.40	2.52	19542	
	Crop + poplar in block + livestock	188.84	384.73	314.83	16.78	26.64	1.37	2.19	25079	
2.	<b>Marginal factor cost (MFC) (Rs.)</b>									
	Farming systems with poplar in boundary	55	200	500	5.4	8.2	1	1	7823	
	Farming systems with poplar in block	55	200	400	5.4	8.2	1	1	8776	
	3.	<b>Profitability ratio (MVP/MFC)</b>								
		Crop + poplar in block	1.77	-	-	0.79	0.82	2.30	-	-
Crop + poplar in boundary		3.07	-	2.89	-	1.77	1.44	3.05	-	
Crop + poplar in boundary + livestock		-	2.99	2.38	1.80	4.90	1.40	2.52	2.49	
Crop + poplar in block + livestock		3.43	1.92	0.78	3.10	3.25	1.37	2.19	2.85	

Marginal value product of expenditure on seed material was highest in crop + poplar in block farming system.

Plant protection chemicals contributed maximum to the gross returns in crop + poplar in boundary farming system followed by crop + poplar in boundary + livestock farming system.

Milch animals were found to be the most productive enterprises as they were contributing very high to the gross returns of a farming system. Their productivity was Rs. 25079 per farm in case of crop+poplar in block +livestock farming system. While MVP of milch animals was slightly lower in case of crop + poplar in boundary with livestock farming system i.e. Rs.19542 per milch animal.

The ratio of the marginal value product of human labour to its factor cost worked out to be highest i.e. 3.43 in crop + poplar in block + livestock farming system. Thus there was suboptimal use of human labour in this farming system. This may be because of the highest productivity of labour in this farming system.

Even in the other two farming systems i.e. crop + poplar in block and crop + poplar in boundary, the human labour was being used sub-optimally.

Tractor power was also being used below optimum level in case of crop + poplar in boundary + livestock and crop + poplar in block + livestock farming system. As the added returns were higher than the added cost for tractor power in both farming systems.

Ratio of marginal value products of irrigation to its factor cost in the farming systems having poplar as boundary plantation were above 2. Irrigation applied to crops were too little by the farmers in both the cases. Part of the reason was lack of irrigation facilities of their own in Haldwani block as it is already mentioned that maximum farms with boundary plantations belonged to Haldwani block.

Urea and DAP were being excessively used in crop + poplar in block farming system as the ratio of their MVP to their MFC were 0.79 and 0.82 respectively. They were sub-optimally used by the farmers in crop + poplar in block + livestock farming system. DAP was the most under utilized input in case of crop + poplar in boundary + livestock farming system (profitability ratio was 4.90). The explanation behind this under utilization of fertilizer was that the farmers adopting livestock as an enterprise in their farming system were utilizing FYM as the fertilizer on their farms, thus their consumption of urea and DAP was lower. Average quantity of DAP used per hectare in crop + poplar in boundary + livestock farming system was 110 kg while in crop + poplar in block + livestock farming system it was 117 kg per hectare. Among the other farming systems crop + poplar in block was using 152 kg DAP per hectare and crop + poplar in boundary farming system was using 129 kg DAP per hectare.

Seed materials were almost optimally used in all the farming systems except in case of crop + poplar in block farming system where the ratio of marginal value product of seed material to its marginal factor cost was 2.30.

Seed materials emerged out to be the significant variable (Table 5.3.1) in crop + poplar in block farming system, so expenditure on this input can be increased to receive higher gross returns.

Scope of increasing expenditure on plant protection chemicals was also there as the profitability ratio for this resource was 3.05, 2.52 and 2.19, respectively for crop + poplar in boundary, crop + poplar in boundary + livestock and crop + poplar in block + livestock farming systems.

Milch animals were sub optimally utilized in both the farming systems having livestock enterprises as the profitability ratio of milch animals were greater than two in both the farming systems.

The results discussed above indicate that there is a scope to increase use of irrigation in crop + poplar in boundary farming and crop + poplar in boundary + livestock farming systems. Irrigation was significantly affecting gross returns (Table 5.3.1) in these farming systems.

Use of human labour can also be increased on crop + poplar in block farming and crop + poplar in boundary farming systems. Though the human labour was used below optimum level in crop + poplar in block + livestock farming system also. But in this particular farming system it did not emerge out to be a significant variable. Therefore, it is doubtful if the reallocation of use of labour in this farming system would affect the gross returns significantly.

There also exists scope of more use of DAP in the crop + poplar in boundary + livestock farming and crop + poplar in block + livestock farming systems.

It could be inferred that in the study area, there is a scope to increase gross returns per farm by increasing the expenditure on various under utilized resources in different farming systems like, human labour in crop + poplar in boundary and crop + poplar in block + livestock farming systems, irrigation in farming systems having poplar in boundary, urea in crop + poplar in block + livestock, DAP in farming systems having livestock component and plant protection chemicals in all the farming systems except crop + poplar in block .

#### **5.4 Optimum enterprise combination in different farming systems involving poplar**

The optimum farm plans were developed for the four identified farming systems. These were crop + poplar in block, crop + poplar in boundary, crop + poplar in boundary + livestock and crop + poplar in block + livestock farming systems. The farm plans were developed to examine and explore the possibilities of increasing farm income and its effect on employment. The optimum farm plans derived for the aforesaid farming systems are discussed below.

##### **5.4.1 Levels of net returns over variable costs in different optimal farm plans for different farming systems**

This section deals with the income generation possibilities of different farming systems both in existing situation and optimum plans.

###### **5.4.1a Crop + poplar in block farming system**

The optimum farm plan along with the existing plan is presented in Table 5.4.1a.

The table reveals that the levels of existing crop rotations followed on the farm have noticeably changed in the optimum plan. In the existing plan the block plantation under poplar acquired 37.60 per cent of the total cultivated area. While, the area under poplar in block has been reduced to 1.25 hectare i.e. 25.83 per cent of the total cultivated area in the optimum plan. In the existing plan paddy (non basmati)- lahi-sunflower and paddy (non basmati)- pea crop rotations jointly accounted for 20.66 per cent of the total cultivated area (4.84 hectare). However, in optimal plan these two crop rotations found no place. The crop rotation paddy (basmati)-wheat-summer paddy obtained the maximum permissible limit i.e. 0.55 hectare in the optimum plan. This crop rotation was permitted only ten per cent increase in area from its original position. This restriction was thought necessary as paddy cultivation twice in a year is treated as an harmful practice for maintaining land productivity even if it is the most profitable one. The area under sugarcane planted-sugarcane ratoon-wheat crop rotations has increased to the maximum limit specified for this rotation. The average annual returns and costs were imputed for this crop rotation to include it in the model as an annual crop rotation. This estimation was done as, practically, it was necessary for sugarcane planted and sugarcane rotation to be cultivated on equal hectares of land. This rotation appeared as major activity in the optimum plan. The area under sugarcane planted – sugarcane ratoon-wheat doubled in the optimum plan.

**Table 5.4.1a : Optimum combination of different activities under optimum plans in crop + poplar in block farming system**

Activities	Existing situation	Optimum plan
A. Poplar in block (ha)	1.82 (37.60)	1.25 (25.83)
B. Crop activities (ha)		
Paddy (B)-wheat-summer paddy	0.50 (10.33)	0.55 (11.36)
Paddy (NB)-lahi-sunflower	0.60 (12.40)	-
Paddy(NB) – pea	0.40 (8.26)	-
Sugarcane planted-sugarcane ratoon-wheat	1.52 (31.40)	3.04 (62.81)
Net returns over variable cost (Rs.)	206856	223946.10 (8.26*)

\*Percentage increase in net returns over variable cost as compared to existing plan.

Figures in parentheses show the percentage, NB = Non basmati, B = Basmati

The total farm income increased to 8.26 per cent in the optimal plan. It has increased from Rs.206856 to Rs.223946 by reallocation of land and other resources. The optimum plan suggested increase in area under sugarcane. Though the area under poplar in block plantation has decreased in optimum plan even then it was the second most important activity in the optimum plan.

#### **5.4.1b Crop + poplar in boundary farming system**

Table 5.4.1b depicts the optimum plan as well as existing plan. Table shows the change in the combination of different activities taken in this farming system.

Table 5.4.1b reveals that poplar in boundary activity emerged out to be an important activity in the optimum plan. It acquired the maximum permissible limit of 2.5 hectare. The contribution of boundary poplar to net returns over variable cost increased to Rs.13840 which was 13.43 per cent of

the total net income (Rs.103034). It was contributing 11.83 per cent to the total net income of crop + poplar in boundary farming system in the existing plan.

**Table 5.4.1b : Optimum combination of different activities under optimum plans in crop + poplar in boundary farming system**

Activities	Existing plan	Optimum plan
A. Poplar in boundary(ha)	2.12	2.5
B. Crop activities (ha)		
Paddy (B)-wheat-summer paddy	0.60 (22.22)	0.20 (07.41)
Paddy (NB)-lahi-wheat (with boundary pl.)	1.10 (4.63)	1.00 (37.04)
Sugarcane planted-sugarcane ratoon-wheat (with boundary plantation)	0.125 (4.63)	-
Sugarcane planted-sugarcane ratoon-pea (with boundary plantation)	0.875 (32.41)	1.50 (55.56)
Net returns over variable cost per farm (Rs.)	99176	103034 (3.89*)

Figure in parentheses are the percentages.

\*Percentage increase in net income in optimum plan over existing plan.

The crop rotation paddy (basmati)-pea-summer paddy obtained only the minimum required area i.e. 0.2 hectare. The restriction was put to this rotation for meeting the on farm consumption demand of paddy (basmati) per farm.

Paddy (non basmati)-lahi-wheat rotation with boundary plantation marginally lost its area under optimum plan. The area under this crop rotation decreased by 0.10 hectare. Thereby the share of this rotation to the net returns over variable costs per farm per annum decreased too. The share was 40.74 per cent in existing plan. It decreased to 37.04 per cent of the net income per farm per annum in optimum plan.

The rotation sugarcane planted-sugarcane ratoon-wheat completely lost its share in optimum plan. Though even in the existing plan it was acquiring very small share in the total area (4.63 per cent). Another rotation of sugarcane

which was including pea after sugarcane ratoon appeared as the most profitable activity as it acquired all the area which was permitted for sugarcane.

The increase in total net returns over variable cost in the optimum plan was only 3.89 per cent with respect to the income in existing plan (Rs.99176).

Thus there is the minor scope of increase in net returns over variable cost in crop + poplar in boundary farming system. Increase in area under rotation sugarcane planted-sugarcane ratoon-pea and further increase in the plantation of boundary poplar, can help in increasing the income of farmers per farm per annum.

#### **5.4.1c Crop + poplar in boundary + livestock farming system**

Optimum and existing plans for this farming system are presented in Table 5.4.1c. Table reveals a significant increase in total net returns over variable costs in optimum plan by 31.86 per cent. Optimum plan consumed all the available area of 4.04 hectare. Boundary poplar gained 4.04 hectare in optimum plan which was the maximum specified area for this activity. In existing plan poplar was grown on the boundary of 3.62 hectare land. The livestock activities which were having 16.14 per cent share to the total net income were now contributing 27.45 per cent to the total net income per farm per annum. The net returns over variable costs from livestock activities increased in optimum plan on account of the addition of three more cross-bred cows in optimum plan. Indigenous cow rearing was not recommended in the optimum plan.

Thus optimum plan included four crossbred cows while in existing plan farmers were taking one crossbred and one indigenous cow on an average farm.

Paddy (non-basmati) – wheat-vegetables with boundary plantation of poplar emerged out to be the most preferred crop rotation in optimum plan. The area under this rotation was almost doubled in the optimum plan over the existing one. The aforesaid rotation was engaging 34.16 percent to the total cultivated area in existing plan. Thus the share of this rotation doubled in the optimum plan. The optimal plan suggested a decrease in area under sugarcane and fodder (with boundary poplar). Fodder (with boundary poplar) could appear upto the minimum permissible limit. Optimum plan completely ignored the rotations paddy (basmati)-pea-tomato and paddy (non-basmati)-wheat with boundary plantation.

Table 5.4.1c clearly shows that inclusion of livestock enterprises in the farming system greatly helped to increase the possibilities of increase in income. In the prior discussed two farming systems, livestock activity was not included and there existed smaller scope of increasing income in those farming system. Thus livestock emerged out to be the major activity for this farming system. Further the optimum plan also suggested the increase in area under vegetables with the paddy-wheat to explore the possibilities of generating more returns in comparison to the existing one.

**Table 5.4.1c : Optimum combination of different activities under optimum plan in crop + poplar in boundary + livestock farming system.**

	Activities	Existing plan	Optimum plan
A.	Poplar in boundary (ha)	3.62	4.04
B.	Crop activities (ha)		
	Paddy (B)-pea-tomato	0.42 (10.40)	-
	Paddy (NB)-wheat-vegetable (with boundary plantation)	1.38 (34.16)	2.78 (68.81)
	Paddy (NB)- wheat (with boundary poplar)	0.20 (4.95)	-
	Sugarcane planted (with boundary poplar)	1.56 (38.61)	0.86 (21.28)
	Kharif fodder-rabi fodder	0.48 (11.88)	0.40 (9.90)
C.	Livestock activities (number)		
	Cow (crossbred)	1	4
	Cow (indigenous)	1	-
	Bullock	2	2
	Net returns per farm	238577	314589 (31.86*)

Figure in parentheses are the percentages.

\*Percentage increase in net income in optimum plan over existing plan.

#### 5.4.1d Crop + poplar in block + livestock farming system

Table 5.4.1d presents the existing and optimum plan for this farming system. Combination of different activities and net returns over variable costs generated by them are shown in this table.

Table shows an increase in net returns over variable costs in optimum plan by 35.52 per cent . Both crop rotation activities and livestock activities were responsible for this increase. As the share of both enterprises to the total net income per farm increased in the optimum plan.

Poplar in block did not emerge out to be the important activity in the existing plan and appeared with its minimum required limit. This limit was put to the activity keeping in view the environmental considerations and fuel wood requirement per farm. The area in poplar as block plantation was only 9.62 per cent of the total area under optimum plan while in the existing plan block poplar was engaging 30.39 per cent of the total available cultivable land. As a result the share of poplar in total net income per farm per annum also decreased drastically.

**Table 5.4.1d : Optimum combination of different activities under optimum plan in crop + poplar in block + livestock farming system.**

	Activities	Existing plan	Optimum plan
A.	Poplar in boundary (ha)	1.58 (30.39)	0.5 (9.62)
B.	Crop activities (ha)		
	Paddy (B)-pea-summer paddy	0.59 (11.35)	0.649 (12.48)
	Paddy(NB)-lahi-potato	0.73 (14.04)	1.46 (28.08)
	Paddy(NB)-pea	0.32 (6.75)	-
	Sugarcane-ratoon-wheat	1.52 (29.23)	2.19 (42.12)
	Kharif fodder-rabi fodder	0.35 (6.73)	0.40 (7.69)
C.	Livestock activities (number)		
	Cow (cross-bred)	1	1
	Cow (indigenous)	1	-
	Buffalo (Murrah)	1	5
	Total cultivated area	5.20	5.20
	Net returns per farm (Rs.)	283741	384540 (35.52*)

Figures in parentheses are the percentages.

\*Percentage increase in net income in optimum plan over existing plan.

Among crop rotation activities optimum plan considered sugarcane planted-sugarcane ratoon-wheat as the major rotation. The area under this rotation was considerably increased. The crop rotation paddy (basmati)-pea-summer paddy acquired the maximum specified area, this specification was necessary to discourage the growing of paddy twice in a year.

The area under paddy (non basmati)-lahi-potato rotation also increased by 0.73 hectare. Thus it was doubled in the optimum plan. Fodder crops attained the minimum permissible area. Paddy (non-basmati) pea crop rotation had completely lost its share in the total area under optimum plan.

Similar to the crop + poplar in boundary + livestock farming system, indigenous cow could not find any place in the optimum plan of this farming system too. This farming system suggested the rearing of one cross-bred cow and five buffaloes per farm. Thus four buffaloes were added in the optimum plan and one indigenous cow was removed as well.

Thus, buffaloes among livestock and sugarcane planted -sugarcane ratoon -wheat & paddy (non-basmati) -lahi-potato among crop rotation activities appeared as major enterprises in the optimum plan of crop + poplar in block + livestock farming system. Optimum plan showed maximum scope to increase income per farm in this particular farming system as compared to others.

As far as agroforestry is concerned the optimum plans showed the preference for poplar in boundary but not for the poplar as block plantations. Oilseeds, vegetables and sugarcane appeared to be the profitable crop activities.

#### **5.4.2 Level of on farm employment in different optimal farm plans for different farming systems**

The human labour utilization by different farming systems in existing and optimum plan is presented here. This section discusses the employment potential generated through various farming systems in the existing and the optimum plans.

##### **5.4.2a Crop + poplar in block farming system**

Table 5.4.2a presents the on-farm labour employment status under existing and optimum plan for crop + poplar in block farming system. The human labour use per annum showed a marginal decrease for poplar in block enterprise in this farming system. This was obvious as the area under block plantation of poplar has decreased in optimum plan (Table 5.4.1a).

But the on-farm employment generated through crop enterprises has increased. The crop enterprises accounted for an employment generation of 475 labour days in the existing plan. This status has increased to 26.90 per cent in the optimum plan. The optimum plan was generating a total employment of 703 human labour days as compared to the existing plan which was generating a employment of 620 human labour days. The per hectare employment generation showed an increase of 13.47 per cent in the optimum plan.

**Table 5.4.2a : On-farm employment in optimal plan in crop + poplar in block farming system**

Particulars	(man-days)	
	Existing plan	Optimum plan
Poplar in block	145	100 (-31.03)
Crops	475	603 (+26.9)
Total on-farm employment	620	703 (+13.8)
Per hectare on farm employment	128	145 (+13.47)

Figures in parentheses are the percentage increase in on-farm employment

#### 5.4.2b Crop + poplar in boundary farming systems

The human labour employment generation by optimum plan as well as by the existing plan is presented in Table 5.4.2b.

Table reveals that there are not much possibilities of increase in employment by the increase in boundary plantation of poplar. Poplar in boundary activity in optimum plan showed a minor increase in human labour employment generated by it. Boundary poplar was giving employment to 7.5 labour days in existing plan. In optimum plan employment increased only by one labour day.

Different crop rotations were giving employment to 469.5 labour days in existing plan. In optimum plan crop enterprises were generating the major share of the total employment per farm. But there was a decrease in this employment in optimum plan by 0.75 per cent. Optimum plan was generating an employment of 466 days by crop enterprises while in existing plan different crop rotations were jointly generating an employment of 469.5 labour days.

**Table 5.4.2b : On farm employment in optimal plan in crop + poplar in boundary farming system**

Particulars	(man-days)	
	Existing plan	Optimum plan
Poplar in boundary	7.5	8.5 (+13.33)
Crop rotation activities	469.5	466 (-0.75)
Total	477	474.5 (-0.52)
Per hectare employment	177	175.74 (-0.71)

Figures in parentheses shows the percentage change in employment in optimum plan over existing plan.

Total on farm employment per farm per annum also decreased by 0.52 per cent in optimum plan. Similar was the state of per hectare on farm employment which decreased by 0.71 per cent in the optimum plan in comparison to the existing one.

Thus optimum plan was generating more income but lesser on farm employment.

#### 5.4.2c Crop + poplar in boundary + livestock farming system

Table 5.4.2c shows the on-farm employment generation in this farming system both in existing and optimum plan.

**Table 5.4.2c : On farm employment in crop + poplar in boundary + livestock farming system**

Particulars	(man-days)	
	Existing plan	Optimum plan
Poplar in boundary	12	13.3 (+10.83)
Crop rotation activities	696	622.7 (-10.53)
Livestock activities	284	466 (+64.08)
Total	992	1102 (+11.09)
Per hectare employment	459	623 (+35.80)

Figures in parentheses shows the percentage change in employment in optimum plan over existing plan.

Table depicts that total on farm employment increased by 35.80 per cent in optimum plan as compared to existing plan. Optimum plan was generating a total employment of 623 labour days. The contribution of poplar in total employment did not increase noticeably even after increase in area. It was generating only an employment of 13.3 human labour days. Though maximum contribution to total employment was from crop enterprises both in existing and optimum plan but total employment generated from crop enterprises decreased by 10.53 per cent in optimum plan with respect to existing plan. The employment generated by livestock enterprises increased drastically (by 64.08 per cent) in optimum plan. This was on account of the increase in number of milch animals (crossbred cows) per farm in optimum plan. Thus livestock enterprises appeared to be significant employment generating one.

Per hectare employment also increased in optimum plan by 35.80 per cent. The credit for this increase goes mainly to livestock enterprises. Thus on an average the optimum plan in crop + poplar in boundary + livestock farming system proved to be favourable for employment generation.

#### **5.4.2d Crop + poplar in block + livestock farming system**

On farm employment and contribution of different enterprises in generating human labour employment in this farming system is presented in Table 5.4.2d.

**Table 5.4.2d : On farm employment in crop + poplar in block + livestock farming system**

Particulars	(man-days)	
	Existing plan	Optimum plan
Poplar in boundary	132	42 (-68.18)
Crop rotation activities	583	853 (+46.31)
Livestock activities	287	608 (+111.85)
Total	1002	1503 (+50.00)
Per hectare employment	425	780 (83.50)

Figures in parentheses shows the percentage change in employment in optimum plan over existing plan.

From Table 5.4.2d it is evident that the optimum plan proved itself to be very much favourable for employment generation. Both crop enterprises and livestock enterprises were generating more employment in optimum plan over the existing one. Employment generated from poplar in block plantation decreased due to decrease in area under this activity in optimum plan. On farm employment from crop enterprises was improved by 46.31 per cent as compared to the existing plan. Livestock activities increased the on farm employment per annum drastically i.e. by 111.85 per cent. The reason behind this was the addition of four milch animals (buffalo) in the optimum plan.

The overall employment per farm per annum increased by 50 per cent in optimum plan. Similarly per hectare on farm employment also showed an increase of 83.50 per cent.

Thus the optimum plan in the farming system crop + poplar in block + livestock proved to be very significant employment generating one.

### 5.4.3 Magnitude of income and employment per hectare in optimum plan in different farming systems

A comparative analysis was performed to explore the per hectare income and employment generating potential of different farming systems in optimum plans. Table 5.4.3 presents the on farm employment and net returns over variable cost for different farming systems under optimum plan.

**Table 5.4.3 : Income and employment generation in optimum plans of different farming systems(per hectare)**

Farming systems	Net returns over variable costs per hectare (Rs.)	On farm employment (per hectare) in labour days
Crop + poplar in block	46270	145
Crop + poplar in boundary	38161	176
Crop + poplar in boundary + livestock	142855	623
Crop + poplar in block + livestock	179654	780

Table 5.4.3 clearly indicates that the farming systems including livestock enterprises as its component were giving drastically higher income as well as employment in comparison to others. At one glance it seems that the farming system having block plantation of poplar were generating more income in comparison to their equivalent farming system with boundary poplar i.e. net returns from crop + poplar in block farming system were more than that from crop + poplar in boundary farming system and crop + poplar in block + livestock farming system was producing more income than crop + poplar in boundary + livestock farming system. But the credit to these higher net returns

can not be given to poplar in block enterprises as optimum plan in both the farming systems having poplar in block reduced the area under this activity in optimum plan (as discussed earlier). The reason behind the lower returns in the farming systems having boundary poplar was the reduction of yield of different crop activities with boundary poplar due to the shade of the trees. While the same activities were producing higher output in the farming systems including block poplar as they were not raised under the shades of the boundary poplar.

Livestock enterprises appeared to be crucial activities for a significant increase in income of a farmer in any type of farming system. The animals rearing also enhanced the status of on farm employment to an appreciable extent. Crop + poplar in block + livestock farming system emerged out to be the maximum income and employment generating farming system.

## **5.5 Different types of constraints faced by the producers in adoption of poplar**

The level of profit from farm business depends to great deal on the efficient production and marketing systems. Thus it was thought necessary to identify the constraints which farmers faced in the production and marketing of poplar. The present section has been devoted to take into account such constraints and describe them under different heads.

### **5.5.1 Technical constraints**

The detailed information was procured of the problems, farmers were facing with the practice of growing poplar and with the other operations followed on the farm.

The important technical aspects on which information was sought from the poplar growers are given in Table 5.5.1. The farmers were asked to supply information on these aspects in yes or no and finally their views were expressed in percentages.

Table 5.5.1 shows that problem of fragmented land holding was faced by only one farmer. Thus fragmented land holding was not the general problem with farmers for poplar cultivation.. Various varieties (mainly developed by WIMCO) were available to farmers. Farmers were also procuring planting material from local nurseries. Therefore, availability of desired variety in required amount was fully assured. About ten per cent of the total farmers were facing the problem of poor quality of seedlings which died in early stages of planting. This problem existed with the farmers who were not directly purchasing their plant materials but getting through intermediaries. This problem mainly existed in Haldwani block as farmers of this block were comparatively naive in adoption of poplar. Lack of technical know-how was not a significant constraint as specialized labour was available for planting of seedlings.

A significant number of farmers i.e. 38.6 per cent of the total sample farmers were struggling with the problem of insect pest and diseases in poplar. The insects developing on the tree were causing great damage to intercrops specially wheat. Farmers were using alternative recommended insecticide and pesticides but no insecticide was fully successful to remove the disease. About six per cent farmers with low capital resource were feeling the paucity of

**Table 5.5.1 : Number and percentage of sample farmers facing technical constraints in poplar cultivation**

Sl. No.	Constraints faced by the farmers	Number of farmers	Percentage of total number of farmers
1.	Fragmented lands	1	0.84
2.	Non availability of recommended variety in required amount	-	-
3.	Poor quality of plant material	12	10.08
4.	Lack of technical know-how	3	2.52
5.	Susceptible to insect pests and diseases	46	38.66
6.	High cost/lack of money	7	5.88
7.	Low yielder	46	38.66
8.	Complicated practice	-	-
9.	Paucity of labour/higher cost of labour charges	11	9.24
10.	High cost of inorganic fertilizer	57	47.90
11.	Lack of irrigation during peak period	33	27.73
12.	Closing of canal during peak period	-	-
13.	Higher irrigation charges	1	0.84
14.	Lack of knowledge for applying fertilizer/ insecticides/herbicides	51	42.86
15.	Lack of knowledge about appropriate pruning	13	10.92
16.	Watchward and maintenance is complicated	-	-

money for investment in poplar but otherwise money was not a problem with farmers.

Poplar as such did not emerge out to be low yielder but due to aforesaid problems of insect pests and diseases, trees of many farmers were damaged completely specially in Haldwani block. These pests were eating the stem of the tree from inside and because of no outer sign of damage on trees farmers were completely ignorant of the disease. They had come to know about it only when the tree lost its vigour.

All the farmers were comfortable with the practice of growing poplar. They did not treated it as cumbersome practice.

Paucity of labour was not a problem in general but 9.24 per cent farmers complained about the higher cost of labour during peak season even when supply of labour was not low.

Farmers were also feeling that fertilizers prices were high. 47.90 per cent farmers were not able to apply recommended quantity of fertilizers due to their high cost.

Farmers of Haldwani block were not having their private source of irrigation and thus they were facing lack of irrigation facility as time and quantity of state tubewell irrigation facility was fixed and not sufficient according to the demand for irrigation specially when rainfall was low.

One farmer expressed that irrigation charges are very high. These were Rs.20 per hour in peak season and Rs.12 per hour in normal season. In Rudrapur block charges were fixed to Rs.18 per hour throughout the year.

About 43 per cent of the total sample farmers were not aware of the correct time and method for applying fertilizers/ insecticides/ herbicides/ pesticides.

Farmers were also having inadequate knowledge about appropriate pruning. About ten per cent of the total sample farmers did not know that poplar should not be pruned in first year and even in second year minor pruning should be done otherwise it checks the proper growth of poplar.

No farmer had said that watching or maintenance of poplar was cumbersome.

### **5.5.2 Constraints to poplar intercropping system**

Questions were asked specially for the constraints in growing intercrops between poplar plantation. The percentages of positive or negative responses regarding these queries are presented in Table 5.5.2.

Table 5.5.2 reveals that no farmer was facing any complication in planting/ sowing and intercultural operations of intercrops.

About 11 per cent farmers were not comfortable with the application of plant protection measures as these measures differed significantly for main crop and intercrop and thus effecting each other negatively.

Poplar yield was not suppressed by the intercrops (though vice-versa was found true).

Only 3.36 per cent farmers growing poplar with intercrops said that root system of these trees got weakened.

**Table 5.5.2 : Number and percentage of sample farmers facing constraints to poplar intercropping system**

Sl. No.	Constraints faced by the farmers	Number of farmers	Percentage to total number of farmers
1.	Complications in planting/sowing	-	-
2.	Waterlogging situation during planting season	-	-
3.	Complication in inter-cultural operation	-	-
4.	Uneasiness in application of plant protection measures	13	10.92
5.	Difficulty in harvesting of intercrops	7	5.88
6.	Suppression of main crop due to intercrop	-	-
7.	Damage of root system	4	3.36
8.	Not control over weeds	71	59.66

About 60 per cent of the total farmers were facing severe problem of weeds between intercrops. The operation of weeding became complicated and costly affair. The problem of weeds was not that much visible in the same type of crops which were grown without poplar plantation.

### **5.5.3 Socio-economic constraints**

Many of the farm management decisions are influenced by social problems. Social problems are related with the human nature, religion, psychology etc and to a great extent, they affect the decision making process on farms. Further, since, poplar provided returns to the farmers after a span of seven years, it was considered necessary to examine whether poplar growers also faced some socio-economic constraints in raising the same. The important socio-economic aspects about which enquiry was made from the poplar growers are given in Table 5.5.3.

Table 5.5.3 depicts that out of total 119 farmers only one farmer was facing the hazard of wild animals while 9.24 per cent farmers experienced the problem of theft and uprooting of plant. All these farmers were growing poplar on the sides of canal.

Four per cent farmers were not ready to borrow to grow poplar at current rate of interest (11.1%).

About half of the sample farmers said that the cost of seedling was high. This rate varied from Rs.6 per seedling to Rs. 15 per seedling. The rate depended on the source from where the seedlings were purchased.

**Table 5.5.3 : Number and percentage of sample farmers facing socio-economic constraints in poplar cultivation**

Sl. No.	Constraints faced by the farmers	Number of farmers	Percentage to total number of farmers
1.	Hazards at wild animals in initial stages	1	0.84
2.	Lack of credit facility	-	-
3.	Problem of procuring the desired amount of loan	16	13.44
4.	Loan available but at high rate of interest	5	4.20
5.	High cost of input	60	50.42
6.	Problem of theft/uprooting of plants	11	9.24
7.	Inadequate power supply	35	29.41
8.	Poor linkage with extension agency	70	58.82
9.	Lack of transport	-	-
10.	Any other reason	-	-

Farmers, purchasing seeds from WIMCO or some reputed nursery, were facing the problem of high cost of input.

Inadequate power supply emerged out to be an important problem specially in Haldwani block. As due to absence of power supply many farmers missed their turn for irrigation from state tubewells.

In Rudrapur block farmers were very much progressive and keen to learn new things if they can help them to produce and thereby earn more. But they were not finding any reliable source to give them useful information. About 59 per cent farmers complained for poor linkages with extension agencies. Even they were not satisfied with the information generated through WIMCO and Pantnagar. Farmers had doubt on practical feasibility of suggestions coming from these institutions.

#### **5.5.4 Constraints in marketing of poplar**

Out of several systems currently being followed by sample farmers for marketing of poplar, the most pronounced one was sale of poplar to timber contractor. About 2.5 per cent farmers who were also employed in WIMCO were selling their poplar to WIMCO. About 2.0 per cent farmers were having their own small plywood factory. Some farmers of Haldwani block were also selling their timber directly to the factory. Various questions were asked to all these farmers regarding constraints faced by them in marketing. The percentage of responses of farmers on some important aspects discussed with them are presented in Table 5.5.4.

**Table 5.5.4 : Number and percentage of sample farmers facing constraints in marketing of poplar**

Sl. No.	Constraints faced by the farmers	Number of farmers	Percentage to total number of farmers
1.	Over production in the area hence low price of product	114	95.80
2.	Undeveloped markets for sale of product	70	58.82
3.	Lack of knowledge about marketing agencies	33	27.73
4.	Number of intermediates quite large	-	-
5.	Lack of guarantee of disposing trees at maturity	-	-
6.	Lack of infrastructure (transport/road/nearness of sale point means)	-	-

Table 5.5.4 reveals that over production in the study area resulted into glut of timber of poplar and thus reduced average price per tree from Rs.1000 to Rs.500 in last ten years. Thus farmers did not receive the expected returns by poplar. 95.8 per cent farmers were disappointed with the price of poplar.

Though on one hand it was very much comfortable to sell the poplar to timber contractor and plywood factories as they purchased poplar as standing crop directly from fields and all the marketing services i.e. harvesting, transportation etc were performed by these market functionaries themselves. But this created their monopoly too. These timber contractors and factory agents manipulated the prices, giving reason of low diameter and low volume of trees. Farmers were having no choice but to accept them as over production handicapped their bargaining power.

Among all the aspects examined to identify the constraints in poplar cultivation, the constraints in marketing emerged out to be the most important one. Almost all the farmers were facing the low price problem.

Other than the above discussed queries farmers were also asked if they were facing any other problem in growing of poplar. It was observed that there was no other aspect which showed any impact either on failure or successful cultivation of poplar plantations in the study area. There were some farmers who complained about the adverse effect of poplars on crop yields due to shade and leaf fall in rabi season.

In a nutshell the most important constraints which were hampering farmers to grow poplar were incidence of insects, pests, diseases, weeds and

low prices of poplar. Farmers were aware of the importance of trees to the environment and willing to adopt them as the component of their farming system if it can assure them good returns even at higher cost and capital intensive techniques.

## **SUMMARY AND CONCLUSIONS**

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Our country was facing great crisis of food during sixties of 20<sup>th</sup> century. The one way concern towards meeting this food demand for growing population ignored the demand for fuel, fodder, timber etc which was also increasing with population growth. But, it is realized that emphasis on agriculture for more farm production without equal emphasis on forestry and grazing land is indeed counter productive, we are left with little forest cover. The reason behind this is that a series of economic measures for rapid expansion in agriculture, industry, transport, employment and other infrastructure have viciously attacked and degraded our forest in last 50 years. Thus now we can not temper with the remaining forest cover to meet the growing demand of forest products because of the concern for environmental security. The only option left is to utilize the cultivable land for both purposes i.e. to produce agricultural products as well as forest products. This can be done by adopting agroforestry, which is primarily the technology of using perennial vegetation in combination with seasonal or perennial field, crop, fodder, or other enterprises of economic value in agriculture.

During the last decade agroforestry has gained importance as a part of farming systems in the plains of Kumaon region of Uttaranchal. The impact of different forms of farming systems involving agroforestry on the cropping

pattern, resource productivity, input use, demand for labour and wage rates need to be studied to decide the efficient reallocation of scarce farm resources between the sub sectors of these farming systems such as crops, livestock and agroforestry etc. Thus it was thought necessary to identify the different farming systems involving agroforestry in the plains of Kumaon region of Uttaranchal, to study their characteristic features, their resource use efficiency and thereby develop an optimum farm plan for these farming systems.

The specific objectives of the study were:

1. To identify and characterize important farming systems involving agroforestry in the plains of Kumaon region.
2. To work out economics of the identified important farming systems.
3. To examine resource use efficiency of these farming systems.
4. To develop optimum plans for these farming systems.
5. To study various constraints related to adoption of agroforestry.

The plain portion of Kumaon region of Uttaranchal was selected purposively, as there is wide scope of growing multipurpose trees in this area due to the well developed plywood, match wood and paper industries around the vicinity of this area. Udham Singh Nagar and Nainital districts were selected as representative districts of Tarai and Bhabhar zone of the plains of Kumaon region respectively.

Rudrapur block from U.S. Nagar and Haldwani block from Nainital districts were selected randomly. Then three village development circles from

Rudrapur block and four village development circles from Haldwani block were chosen by random selection. From a complete list of farmers adopting agroforestry in these village development circles, seven groups of farmers were made separately for each block, according to the age of tree grown by the farmers as agroforestry component. Fifteen per cent of the total farmers in each age group were randomly selected subject to a minimum of five. Final sample consisted a total of 123 farmers.

The information required for the study was collected both from primary as well as secondary sources.

Primary data was obtained from the sample farmers through personal interviews with the help of pretested schedule. The data pertained to agricultural year 2002-2003.

The secondary data was collected through personal visits of district and block offices and further from different published sources.

To achieve first objective, the farming systems involving agroforestry which were being followed by ten per cent or more of the total sample farmers were treated as important farming systems.

To work out economics of different activities of a farming system a stream of gross costs, gross returns and net returns per annum were calculated for each activity.

To examine the resource use efficiency in the selected farming systems, Cobb-Douglas type of production function was fitted separately for each

farming system. Then, with the help of the results of the fitted production function, marginal value productivity of the inputs were calculated which were affecting gross returns per hectare, positively.

The ratio of marginal value productivity of these inputs to their marginal factor costs i.e. profitability ratios were then calculated. The profitability ratios were compared with one to examine the efficiency of use of the inputs they were considered in money term and conclusions were drawn as follows:

- If the ratio was less than one the input was treated as over utilized.
- If the ratio was equal/almost equal to unity the input was treated as optimally utilized.
- If the ratio was greater than one then the input was treated as under utilized.

Linear programming technique was used to work out the optimum plans for each farming system with given restrictions. The objective was set to maximize net returns over variable costs for each farming system.

To examine the type, level and extent of constraints faced by the sample farmers in adopting agroforestry, descriptive statistics was used.

The major findings of the study are given below:

- ⇒ Poplar was the only important agroforestry component, which was significantly adopted by the farmers of the study area.
- ⇒ The major farming systems involving poplar as agroforestry component were crop + poplar in block plantation, crop + poplar in boundary

plantation, crop + poplar in boundary plantation + livestock and crop + poplar in block plantation + livestock farming systems.

- ⇒ The average size of land holding varied from one farming system to other. In case of crop + poplar in block + livestock farming system, the size of holding was largest (5.20 hectare) and it was smallest (2.70 hectare) in crop + poplar in boundary farming system.
- ⇒ Family size and family members available for farm work varied between farming systems. The average number of family labour available ranged from 1.96 male equivalent days in crop + poplar in boundary farming system to 3.12 male equivalent days in crop + poplar in block + livestock farming system. The average size of family varied from 6.16 to 8.17 in crop + poplar in boundary farming system and crop + poplar in block + livestock farming system respectively.
- ⇒ Paddy, wheat, pea and sugarcane were the crops, which were being cultivated in each type of farming system. The area occupied by these crops in different farming systems varied noticeably.
- ⇒ All the crop activities (except tomato in crop + poplar in boundary + livestock farming system) were generating positive net returns over variable costs per hectare in different farming systems. Sugarcane was covering its total cost in every farming system. Besides sugarcane, potato and vegetables were also able to cover their total cost of

production in crop + poplar in block + livestock and crop + poplar in boundary + livestock farming system.

- ⇒ Poplar in every form of plantation (boundary/block) was able to generate positive net returns over total cost per hectare.
- ⇒ Maximum net returns over variable costs per hectare were coming from crop + poplar in block + livestock farming system. The farming systems having livestock as their component were able to earn considerably higher income per hectare than the farming systems without livestock component.
- ⇒ The crops grown under boundary poplar were affected negatively by the shade of poplar and were giving low yield as compared to the same crop without boundary poplar.
- ⇒ Maximum employment per hectare was generated by the crop + poplar in boundary + livestock farming system (459 labour days). Crop + poplar in block + livestock farming system was generating an employment of 429 labour days/hectare.
- ⇒ Human labour was found to be over utilized in crop + poplar in boundary + livestock farming system. Average labour days employed per hectare in this farming system were 186 labour days while in all other farming systems this figure was below 150.

- ⇒ Leaving the case of crop + poplar in block farming system, irrigation was an important determinant of increase in gross returns per hectare per farm in other farming systems.
- ⇒ Quantity of DAP used per hectare and expenditure on seed materials were the two variables which were affecting gross returns per hectare significantly in all the farming systems.
- ⇒ The regression coefficients of number of milch animals were found to be highly significant in both the farming systems having livestock component. The addition of one milch animal on a farm was increasing gross returns by around 60 per cent in crop + poplar in boundary + livestock farming system and by 75 per cent in crop + poplar in block + livestock farming system.
- ⇒ When profitability ratios for the inputs which were affecting gross returns per hectare positively were worked out, it was observed that almost all the inputs were under utilized in different farming systems.
- ⇒ Human labour was being used far below optimum level in crop + poplar in boundary and crop + poplar in block + livestock farming systems.
- ⇒ Irrigation was under utilized in crop + poplar in boundary and crop + poplar in boundary + livestock farming systems. These farming systems were mainly prevailing in Haldwani block where farmers were totally dependent on state tubewells and canals and were facing the lack of sufficient irrigation facilities.

- ⇒ Quantity of DAP used per hectare was found to be significantly below optimum level in the farming systems having livestock enterprises.
- ⇒ Plant protection chemicals were also used sub optimally in all the farming systems except crop + poplar in block farming system.
- ⇒ Milch animals were also under utilized enterprises in both the farming systems having livestock component.
- ⇒ There existed scope of increase in income in all the farming systems in optimum plans. This scope varied from 3.89 per cent in crop + poplar in boundary farming system to 35.52 per cent in crop + poplar in block + livestock farming system.
- ⇒ Livestock enterprises generated greater income increasing possibilities.
- ⇒ Poplar in block activity did not emerge out as important activity in any of the farming system having poplar in block enterprises. However, poplar in boundary acquired the maximum possible area under optimum plans of both the farming systems having the activity of boundary poplar.
- ⇒ Sugarcane planted-sugarcane ratoon-wheat crop rotation achieved favour in optimum plan of crop + poplar in block and crop + poplar in block + livestock farming systems. While in crop + poplar in boundary farming system sugarcane planted –sugarcane ratoon-pea crop rotation dominated the aforesaid rotation.

- ⇒ Optimum plan diverted maximum area towards the crop rotation, paddy (non-basmati)-wheat-vegetables with boundary plantation in crop + poplar in boundary + livestock farming system.
- ⇒ Paddy (non-basmati) – lahi-potato emerged out as an important activity in crop + poplar in block + livestock farming system.
- ⇒ Cross-bred cows dominated over indigenous cows and buffalos dominated both cross-bred and indigenous cows in optimum plans with respect to returns.
- ⇒ Optimum plans of both the farming system having livestock enterprises were in favour of increase in number of milch animals.
- ⇒ Except in case of crop + poplar in boundary farming system all other farming systems showed noticeable possibilities of increase in employment under optimum plans.
- ⇒ Maximum per hectare employment was generated under optimum plan of crop + poplar in block + livestock farming system. It was 780 labour days per hectare per annum.
- ⇒ Crop + poplar in block + livestock farming system was also generating maximum net returns over variable costs per hectare (Rs.179654). Minimum net returns over variable costs per hectare were in crop + poplar in boundary farming system.
- ⇒ The most important constraints which were hampering farmers to grow poplar were incidence of insects, pests, diseases on the poplar tree.

Farmers were also disappointed with the low prices of poplar and low bargaining power due to the glut of poplar production.

From the above discussed salient findings it is derived that:

- ⇒ Majority of the farmers (39.52 per cent) are following poplar as block plantation along with the crop and livestock enterprises. Thus farmers should be provided with the technological back up and knowledge of suitable and remunerative methods of growing intercrops with poplar.
- ⇒ Besides taking paddy, wheat and sugarcane farmers were also taking pea, lahi and vegetables in their cropping systems. Better price policies and institutional support may be provided to farmers to promote farmers for diversification towards oilseeds, pulses and vegetables as a measure of income generation, sustainability and nutritional security..
- ⇒ Farmers need to be encouraged to follow the model of crop + poplar in block + livestock farming system to maximize their income, as this farming system was generating maximum net returns over variable costs per hectare (Rs.109890).
- ⇒ Crop + poplar in boundary + livestock farming system was generating maximum employment per hectare (459 labour days) as compared to other farming systems. Thus to catch the full potential of employment generation this farming system can be the best option.
- ⇒ There is need to optimize the use of tractor power on the farm of crop + poplar in block and crop + poplar in boundary farming systems.

- ⇒ Crop + poplar in boundary + livestock farming system shows the considerable over utilization of human labour per hectare on farm. Employment opportunities outside the farm need to be generated to check such kind of disguised employment on farm.
- ⇒ There is need to provide regular electricity to strengthen the irrigation facilities on the farm of Haldwani block because irrigation was found to be under utilized in the farming systems having boundary poplar which were mainly prevailing in Haldwani block. Supply through natural water resources also needs to be regulated.
- ⇒ Quantity of DAP used and expenditure on seed materials were very important determinants to increase the returns of farmers. Thus quality and timely availability of these inputs need to be monitored and made farmer's friendly.
- ⇒ Farmers need to be encouraged to rear milch animals on their farm as the marginal value productivity per milch animal was found to be noticeably high. This will enhance their income as well as nutritional security.
- ⇒ Other than the poplar activity in crop + poplar in block farming system farmers are also suggested to divert their cultivable land to sugarcane planted-sugarcane ratoon-wheat rotation to increase their income.
- ⇒ The farmers which were following crop + poplar in boundary farming system can increase their net income by shifting more area towards

poplar in boundary and sugarcane planted-sugarcane ratoon-pea crop rotation with boundary poplar. In such way they can increase net return over variable cost by about four per cent.

- ⇒ There is scope to increase income by 32 per cent in crop + poplar in boundary + livestock farming system by reallocation of land and number of milch animals. Farmers should increase the area of boundary poplar. They may shift more area towards the crop rotation paddy (non-basmati)-wheat-vegetables with boundary poplar. Cross-bred cows offer more scope to increase income instead of indigenous cows. Hence they need to be promoted for.
- ⇒ Under crop + poplar in block + livestock farming system there exists vast possibilities of increasing income per farm. The preference to the crop rotations, paddy (non-basmati)- lahi-potato and sugarcane planted-sugarcane ratoon-wheat may prove beneficial. The rearing of Murrah buffalos instead of cows will further add to the net returns over variable cost in this farming system. The number of buffalos can be increased per farm to generate attractive returns.
- ⇒ Most important recommendation which emerged from the study is that because there exists larger scope of income and employment generation, in crop + poplar in block + livestock farming system thus this particular farming system can be promoted along with the reallocation of land and number of milch animals as suggested by optimum plan.

- ⇒ Major production constraint faced by the poplar grower was the incidence of disease and pest hence effective plant protection measures need to be developed and promoted.
- ⇒ Market glut usually occurred specially in the Rudrapur block resulting into lower prices, degrading interest in poplar growing and reduced bargaining power of the farmers. This calls for the development of a system of contract farming or future marketing.
- ⇒ It is also noted that though crop + poplar in block + livestock farming system was giving maximum returns to the farmers but, crop + poplar in boundary + livestock farming system was on one hand giving second best returns per hectare and it was also generating considerable employment. So to avoid the over production of poplar, it will be better to grow poplar only on the boundary. It will serve two purposes. Firstly it will benefit to the environment and secondly it will improve the price situation of poplar.

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\*Original not seen.

## APPENDIX I

### Limitations of the study

- (i) The study was not able to incorporate returns from poplar for every individual year of its life as returns from poplar were compared with the returns from annual activities. Thus an average annual picture of costs and returns from poplar was introduced in the model.
- (ii) This happens to be a static study in terms of time as it is confined to one agricultural year i.e. 2002-2003 only. So the generalization, for a longer time period can not be made as the assumption of constant prices of inputs and outputs and the level of technology used to raise crops and livestock, may not remain constant over time.
- (iii) Prior it was proposed to apply multiobjective programming to develop a compromise plan for different farming systems. But after the complete survey of the study area, it was found that objectives of maximization of family labour employment and timber production were not at par with the real situation of the area. Therefore, finally single objective of maximization of net returns over variable costs to develop the optimum farm plan for each farming system was considered in this study.

## APPENDIX-II

Correlation coefficient matrix for crop + poplar in block farming system

	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>
X <sub>1</sub>	1.00	0.401	0.421	-0.337	0.185	0.577	-0.400
X <sub>2</sub>	0.401	1.00	-0.054	-0.549	0.026	0.270	-0.477
X <sub>3</sub>	0.421	-0.054	1.00	-0.011	0.090	0.325	0.443
X <sub>4</sub>	-0.337	-0.549	-0.011	1.00	0.319	-0.280	0.411
X <sub>5</sub>	0.185	0.026	0.090	0.319	1.00	-0.137	-0.155
X <sub>6</sub>	0.577	0.270	0.325	-0.280	-0.137	1.00	-0.214
X <sub>7</sub>	-0.400	-0.477	0.443	0.411	-0.155	-0.214	1.00

### APPENDIX-III

Correlation coefficient matrix for crop + poplar in boundary farming system

	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>
X <sub>1</sub>	1.00	-0.253	-0.101	0.453	-0.152	-0.211	0.058
X <sub>2</sub>	-0.253	1.00	0.175	-0.425	-0.212	0.520	0.305
X <sub>3</sub>	-0.101	0.175	1.00	0.100	-0.197	-0.027	0.366
X <sub>4</sub>	0.452	-0.425	0.100	1.00	0.195	-0.190	-0.022
X <sub>5</sub>	-0.152	-0.212	-0.197	0.195	1.00	0.000	0.023
X <sub>6</sub>	-0.211	0.520	-0.027	-0.190	0.000	1.00	0.270
X <sub>7</sub>	0.058	0.305	0.366	-0.022	0.023	0.270	1.00

## APPENDIX-IV

Correlation coefficient matrix for crop + poplar in boundary + livestock farming system

	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>
X <sub>1</sub>	1.00	0.093	-0.020	-0.098	-0.052	0.272	0.000	0.333
X <sub>2</sub>	0.093	1.00	-0.348	0.059	-0.108	-0.137	0.225	0.067
X <sub>3</sub>	-0.020	-0.348	1.00	-0.062	0.133	-0.151	-0.183	-0.067
X <sub>4</sub>	-0.098	0.059	-0.062	1.00	0.091	0.042	0.335	-0.071
X <sub>5</sub>	-0.052	-0.108	0.133	0.091	1.00	0.237	0.164	-0.132
X <sub>6</sub>	0.272	-0.137	-0.151	0.042	0.237	1.00	-0.201	0.143
X <sub>7</sub>	0.000	0.225	-0.183	0.335	0.164	-0.201	1.00	-0.235
X <sub>8</sub>	0.333	0.067	-0.067	-0.071	-0.132	0.143	-0.235	1.00

## APPENDIX-V

Correlation coefficient matrix for crop + poplar in block + livestock farming system

	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>
X <sub>1</sub>	1.000	0.396	0.032	0.100	0.221	-0.120	0.094	0.208
X <sub>2</sub>	0.396	1.00	-0.065	0.128	0.332	0.017	-0.261	-0.064
X <sub>3</sub>	0.032	-0.065	1.00	0.182	0.104	0.026	-0.099	0.180
X <sub>4</sub>	0.100	0.128	0.182	1.00	0.358	0.103	-0.266	0.152
X <sub>5</sub>	0.221	0.332	0.104	0.358	1.00	0.256	-0.302	0.271
X <sub>6</sub>	-0.120	0.017	0.026	0.103	0.256	1.00	-0.094	0.359
X <sub>7</sub>	0.094	-0.261	-0.099	-0.266	-0.302	-0.094	1.00	-0.140
X <sub>8</sub>	0.208	-0.064	0.180	0.152	0.271	0.359	-0.140	1.00

## APPENDIX-VI

Initial simplex table of linear programming model for crop + poplar in block farming system

Particulars	Activities			Real activities					Lab our hiring			Cash borrowing		Constraints	
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Type	Supply level		
Maximize Z (Rs.)	43181	65469	42853	36319	55314	-55	-55	-0.05	-0.05	0	0	<=	4.84		
Land availability (ha)	1	1	1	1	1	0	0	0	0	0	0	>=	0.40		
Poplar in block minimum (ha)	1	0	0	0	0	0	0	0	0	0	0	>=	0.50		
Wheat minimum (ha)	0	1	0	0	1	0	0	0	0	0	0	>=	0.20		
Paddy minimum (ha)	0	1	1	1	0	0	0	0	0	0	0	<=	0.55		
Summer paddy maximum (ha)	0	1	0	0	0	0	0	0	0	0	0	<=	3.04		
Sugarcane maximum (ha)	0	0	0	0	1	0	0	0	0	0	0	<=	270		
Family labour (mandays) kharif	5	4	6	17	11	0	0	0	0	0	0	<=	270		
Family labour (mandays) rabi	3	8	18	18	11	0	0	0	0	0	0	<=	0		
Hired labour (mandays) kharif	56	49	39	39	77	-1	0	0	0	0	0	<	0		
Hired labour (mandays) rabi	16	63	67	55	77	0	-1	0	0	0	0	<	0		
Cash availability (Rs.) kharif	8499	12063	11549	11549	12718	0	0	-1	0	0	0	<=	56928		
Cash availability (Rs.) rabi	8499	21950	19249	14233	12718	0	0	0	0	0	-1	<=	58469		
Cash borrowing maximum (Rs.) kharif	0	0	0	0	0	0	0	1	0	0	0	<=	145200		
Cash borrowing maximum (Rs.) Rabi	0	0	0	0	0	0	0	0	1	0	0	<=	145200		

Where,

- X<sub>1</sub> = Poplar in block (ha)  
 X<sub>2</sub> = Paddy (basmati)-wheat-summer paddy(ha)  
 X<sub>3</sub> = Paddy (non-basmati)-labi-sunflower(ha)  
 X<sub>4</sub> = Paddy (non-basmati)-pea(ha)  
 X<sub>5</sub> = Sugarcane planted-sugarcane ratoon-wheat(ha)  
 X<sub>6</sub> = Labour hiring in kharif (mandays)  
 X<sub>7</sub> = Labour hiring in rabi(mandays)  
 X<sub>8</sub> = Cash borrowing in kharif (Rs.)  
 X<sub>9</sub> = Cash borrowing in rabi(Rs.)

## APPENDIX-VII

Initial simplex table of linear programming model for crop + poplar in boundary farming system

Particulars	Activities									Cash borrowing			Constraints	
	Real activities			Lab our hiring			Rabi			Type	Supply level			
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	Kharif	Rabi	Kharif	Rabi					
Maximize Z (Rs.)	5693	43496	39347	39228	40259	-55	-55	-0.05	-0.05					
Land availability (ha)	0	1	1	1	1	0	0	0	0			2.7		
Wheat minimum (ha)	0	0	1	1	0	0	0	0	0			0.40		
Paddy basmati minimum (ha)	0	1	0	0	0	0	0	0	0			0.20		
Poplar in boundary maximum (ha)	1	1	0	0	0	0	0	0	0			2.70		
Summer paddy maximum (ha)	0	1	0	0	0	0	0	0	0			0.66		
Sugarcane maximum (ha)	0	0	0	1	1	0	0	0	0			1.5		
Family labour (mandays) kharif	0.5	3	6	17	18	0	0	0	0			240		
Family labour (mandays) rabi	0.5	27	17	7	15	0	0	0	0			240		
Hired labour (mandays) kharif	2	67	89	58	69	-1	0	0	0			0		
Hired labour (mandays) rabi	1	129	43	58	69	0	-1	0	0			0		
Cash availability (Rs.) kharif	232	12610	15805	11287	12407	0	0	-1	0			37710		
Cash availability (Rs.) rabi	232	28376	15536	11287	12407	0	0	0	-1			46874		
Cash borrowing maximum (Rs.) kharif	0	0	0	0	0	0	0	1	0			81000		
Cash borrowing maximum (Rs.) Rabi	0	0	0	0	0	0	0	0	1			81000		

Where,

- X<sub>1</sub> = Poplar in boundary (ha)
- X<sub>2</sub> = Paddy (basmati)-pea -summer paddy(ha)
- X<sub>3</sub> = Paddy (non-basmati)-lahi-wheat(ha)
- X<sub>4</sub> = Sugarcane planted-sugarcane ratoon-wheat(ha)
- X<sub>5</sub> = Sugarcane planted-sugarcane ratoon-pea(ha)
- X<sub>6</sub> = Labour hiring in kharif (mandays)
- X<sub>7</sub> = Labour hiring in rabi(mandays)
- X<sub>8</sub> = Cash borrowing in kharif (Rs.)
- X<sub>9</sub> = Cash borrowing in rabi (Rs.)

**APPENDIX-VIII**

**Initial simplex table of linear programming model for crop + poplar in boundary + livestock farming system**

Activities Particulars	Crop rotation activity						Livestock activities					Labour farming		Cash borrowing		Green fodder purchasing		Dry fodder purchasing		Constraints	
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	Cross bred cow	Indigenous cow	Bull dock	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Type	Supply level	
	4686	42090	70274	36183	46044	23755	21591	16555	0	X <sub>9</sub>	X <sub>10</sub>	X <sub>11</sub>	X <sub>12</sub>	X <sub>13</sub>	X <sub>14</sub>	X <sub>15</sub>	X <sub>16</sub>				
Maximize Z (Rs.)	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	<=	4.04	
Land availability (ha)	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	0.4	
Wheat minimum (ha)	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	1.00	
Paddy minimum (ha)	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>=	0.40	
Fodder minimum (ha)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	>=	0.86	
Sugarcane minimum (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<=	4.04	
Poplar in boundary maximum (ha)	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<=	1.00	
Fodder maximum (ha)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	<=	4.04	
Milch animals minimum (ha)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	<=	1.00	
Draft animal minimum (no.)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	=	2	
Family labour (mandays) kharif	0.5	5	5	5	8	13	45	45	26	0	0	0	0	0	0	0	0	0	<=	282	
Family labour (mandays) rabi	0.25	49	16	5	6	10	45	45	26	0	0	0	0	0	0	0	0	0	<=	282	
Hired labour (mandays) kharif	2	60	65	69	91	19	0	0	0	-1	0	0	0	0	0	0	0	0	<	0	
Hired labour (mandays) rabi	1	184	75	39	85	15	0	0	0	0	-1	0	0	0	0	0	0	0	<	0	
Cash availability (Rs.) kharif	871	9011	11453	11453	19485	6895	5363	4465	1478	0	0	-1	0	0	0	0	0	0	<=	68569	
Cash availability (Rs.) rabi	871	33188	23297	10388	7878	6942	5853	4930	1375	0	0	0	-1	0	0	0	0	0	<=	77724	
Cash borrowing maximum (Rs.) kharif	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	<=	121200	
Cash borrowing maximum (Rs.) rabi	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	<=	121200	
Green fodder purchasing (qtls) kharif	0	0	0	0	0	-390	18	17	15	0	0	0	0	-1	0	0	0	0	<=	0	
Green fodder purchasing (qtls) rabi	0	0	0	0	-135	-685	19	17	15	0	0	0	0	0	-1	0	0	0	<=	0	
Dry fodder purchasing (Quintals)	-28	-30	-88	-88	0	0	15	17	37	0	0	0	0	0	0	0	0	0	<=	0	

Where,

X<sub>1</sub>=poplar in boundary(ha)

X<sub>2</sub>=Paddy (non-basmati)-wheat with boundary poplar (ha)

X<sub>3</sub>=Paddy (basmati)-pea-tomato(ha)

X<sub>4</sub>=Sugarcane planted with boundary poplar (ha)

X<sub>5</sub>=Kharif fodder-rabi fodder (ha)

X<sub>6</sub>=Paddy(non-basmati)-wheat-vegetable with boundary poplar(ha)

X<sub>7</sub>=Cow (cross-bred)

X<sub>8</sub>=Paddy (non-basmati) -wheat with boundary poplar (ha)

X<sub>9</sub>=Sugarcane planted with boundary poplar (ha)

X<sub>10</sub>=Kharif fodder-rabi fodder (ha)

X<sub>11</sub>=labour hiring in kharif (mandays)

X<sub>12</sub>=labour hiring in rabi(mandays)

X<sub>13</sub>=cash borrowing in rabi (Rs.)

X<sub>14</sub>=purchase of green fodder in kharif (qtls)

X<sub>15</sub>=Purchase of green fodder in rabi(qtls)

X<sub>16</sub>= Purchase of dry fodder (qtls)

## APPENDIX-IX

Initial simplex table of linear programming model for crop + poplar in block + livestock farming system

Activities	Crop rotation activity										Livestock activities					Labour farming		Cash borrowing		Green fodder purchasing		Dry fodder purchasing		Constraints	
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>	Indigen cow	Buffalo	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	X <sub>13</sub>	X <sub>14</sub>	X <sub>15</sub>	X <sub>16</sub>	Type	Supply level			
	44586	68927	72829	37340	48677	34382	18196	16040	22335	X <sub>9</sub>	X <sub>10</sub>	X <sub>11</sub>	X <sub>12</sub>	X <sub>13</sub>	X <sub>14</sub>	X <sub>15</sub>	X <sub>16</sub>	X <sub>16</sub>	X <sub>16</sub>	X <sub>16</sub>	X <sub>16</sub>	X <sub>16</sub>	X <sub>16</sub>		
Particulars	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Maximize Z (Rs.)	44586	68927	72829	37340	48677	34382	18196	16040	22335	X <sub>9</sub>	X <sub>10</sub>	X <sub>11</sub>	X <sub>12</sub>	X <sub>13</sub>	X <sub>14</sub>	X <sub>15</sub>	X <sub>16</sub>	X <sub>16</sub>	X <sub>16</sub>	X <sub>16</sub>	X <sub>16</sub>	X <sub>16</sub>			
Land availability (ha)	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.20		
Poplar in block minimum (ha)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50	
Paddy (basmati) minimum (ha)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.30	
Wheat minimum (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.60	
Fodder minimum (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.40	
Summer paddy maximum (ha)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.649	
Lahi and potato maximum (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.46	
Sugarcane maximum (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.26	
Milch animals minimum (No.)	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	
Milch animals maximum (No.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	
Cows minimum (No.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
Family labour (mandays) kharif	7	4	5	5	6	6	44	49	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	384	
Family labour (mandays) rabi	5	21	25	17	4	6	44	49	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	384	
Hired labour (mandays) kharif	40	79	78	79	76	11	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	
Hired labour (mandays) rabi	35	117	99	38	76	12	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	
Cash availability (Rs.) kharif	9073	9697	10996	10996	11614	2895	6221	5040	6035	-	-	-1	0	0	0	0	0	0	0	0	0	0	0	0	68842
Cash availability (Rs.) rabi	8863	23669	30726	12923	11614	4148	6504	5260	6470	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	93150
Cash borrowing maximum kharif	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	156000
Cash borrowing maximum rabi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	156000
Green fodder purchase (qtls) kharif	0	0	0	0	0	-408	14	16	19	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0
Green fodder purchase (qtls) rabi	0	0	0	0	-146	-780	14	16	19	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0
Dry fodder purchase (qtls)	-27	-49	-60	-60	-56	0	12	13	15	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0

Where,

- X<sub>1</sub>=Poplar in block(ha)
- X<sub>2</sub>=Paddy (basmati)-pea- summer paddy(ha)
- X<sub>3</sub>=Paddy(non-basmati)- lahi-potato(ha)
- X<sub>4</sub>=Paddy (non-basmati)-pea(ha)
- X<sub>5</sub>=Sugarcane planted-sugarcane ratoon-wheat (ha)
- X<sub>6</sub>=Kharif fodder-rabi fodder(ha)
- X<sub>7</sub>=Cow (cross-bred)
- X<sub>8</sub>=cow (indigenous)
- X<sub>9</sub>=Buffalo (Murrah)
- X<sub>10</sub>=labour hiring in kharif (mandays)
- X<sub>11</sub>=labour hiring in rabi(mandays)
- X<sub>12</sub>=Cash borrowing in kharif(Rs.)
- X<sub>13</sub>=Cash borrowing in rabi(Rs.)
- X<sub>14</sub>=Purchase of green fodder in kharif(qtls)
- X<sub>15</sub>=Purchase of green fodder in rabi(qtls)
- X<sub>16</sub>=Purchase of dry fodder(qtls)

## APPENDIX-X

Resource requirements in optimum plans under different farming systems

Particulars	Crop + poplar in block		Crop + poplar in boundary		Crop + poplar in boundary + livestock		Crop + poplar in block + livestock	
	Existing plan	Optimum plan	Existing plan	Optimum plan	Existing plan	Optimum plan	Existing plan	Optimum plan
1. Labour (hired)								
Khairf labour	282	331	199	210	287	274	320	356
Rabi labour	240	288	192	174	332	291	403	409
2. Working capital (Rs.)								
Khairf	56928	59045	37710	37710	68569	78727	68842	90621
Rabi	58469	58469	46874	46874	77724	103393	93150	131424
3. Fodder (qtls)								
Khairf green fodder	-	-	-	-	65	102	49	109
Rabi green fodder	-	-	-	-	66	106	49	109
Dry fodder	-	-	-	-	106	134	40	87

**APPENDIX-XI**

1. Name of the Respondent :

2. Village :

3. VDC :

4. Block :

5. District :

6. Family Composition :

Name	Sex	Age	Education	Occupation		Annual Income	
				Main	Subsidiary	Main	Subsidiary

7. Land utilization pattern :

Land revenue :

	Owned	Orchard	Leased in		Leased out		Homestead	Unsuitable for cultivation
			Area	Rental value	Area	Rental value		
Unirrigated								
	Sandy							
	Loam							
Irrigated								
	Sandy							
	Loam							

Appendix – XI : Contd..

**8. Irrigation**

Source of irrigation	Duration of water availability	Ownership	Command area
Canal			
Tubewell			
Diesel pump			
Any other			

**9. Cropping pattern (involving agroforestry)**

Agroforestry component :

Pattern of plantation (Block, boundary etc.) :

No. of blocks :

Area in each block :

Age of plantation :

Intercrops :

Block No.	Kharif (Name, Area and variety)	Rabi (Name, Area and variety)	Zaid (Name, Area and Variety)	Remarks

**10. Cropping pattern (excluding Agroforestry)**

	Crop with variety	Area
Kharif	Irrigated	
	Unirrigated	
Rabi	Irrigated	
	Unirrigated	
Zaid	Irrigated	
	Unirrigated	

**Appendix – XI : Contd..**

**11. Farm Assets :**

**A. Buildings and Improvements**

Kind of investment	Date when acquired	Capacity	Original cost	Estimated life	Beginning of the year		End of the year		Remarks
					Number	Value	Number	Value	
Cattle shed									
Manger									
Storage									
Implements shed									
Poultry shed									
Cemented irri.channel									
Any other									

**B. Machinery and Equipments**

Items	Purchase year	Original price	Estimated life	Junk value	Depreciation	Estimated present value
1. Tractor						
2. Tractor drawn implements						
Disc plough						
Harrow						
Cultivated						
Seed/Fertidrill						
Trolley						
Other						
3. Bullock drawn implements						
Mould based plough						
Desi plough						
Patela						
Others						
4. Sprayer						
5. Thresher						
6. Tubewell						
7. Chaffcutter						
8. Others						

**Appendix - XI : Contd..**  
**C. Livestock**

Kind of livestock	Breed	No.	Year of purchase	Original price	Present value	Min. area	Max. area	Remarks
Drought buffaloes								
Drought cows								
Bullock								
Milch buffaloes								
Milch cows								
Calves (buffaloes)								
Calves (cows)								
Goats								
Poultry birds								
Others								

**12. Credit Information**

**Funds available for investment and expenses**

Source	Agency	Rate of interest	Short term		Medium term	Long term	Maximum limit of borrowing	Remarks
			Kharif	Rabi				
Funds at hand								
Funds which could be borrowed	Agroforestry							
	Crop production							
	Livestock							
	Equipments							

**Farmers indebtedness**

Kind of debt	Source of credit	Borrowing in the year			Payment in the year		
		Amount	Int. rate	Purpose	Principle	Interest	Month
Short term							
Medium term							
Long term							



Appendix - XI : Contd..

15. Cultivation costs/returns

Crop

Variety

Area

Year/Season

No.	Operations	No. of operations	Time of operations	Human labour days						Bullock labour			Tractor machine			Total cost	
				Family		M		Hired		Owned (days)	Days	Hired Rate	Owned OC/hr	Hrs	Hired Rate		
				M	F	C	No.	Rate	No.								Rate
	Ploughing																
	Harrowing																
	Planking																
	Sowing																
	Nursery raising																
	Transplanting																
	Manuring																
	Fertilizer application																
	Irrigation																
	Weeding																
	Pruning and debudding																
	Spraying of chemical																
	Harvesting																
	Threshing																
	Transportation																
	Others																

## Appendix – XI : Contd..

## B. Material cost

Sl.No.	Material	Quantity	Rate	Value	Area covered
1.	Seed				
2.	FYM				
3.	Green manure				
4.	Fertilizer				
	Urea				
	DAP				
	SSP				
	MoP				
	Others				
5.	Plant protection chemicals				
6.	Irrigation				
7.	Others				

## C. Production and Sale

Particular	House hold use	Quantity produced	Quantity sold	Rate	Total returns	Remarks
Main product						
By product						
Intercrop main product						
Intercrop by product						

Appendix - XI : Contd..

16. Cultivation costs/returns

Crop

Variety

Area

Year/Season

A. Operational cost

No.	Operations	No. of operations	Time of operations	Human labour days						Bullock labour		Tractor machine			Total cost			
				Family		M	Hired		Owned (days)	Days	Hired Rate	Hrs	Owned OC/hr	Hrs		Hired Rate		
				M	F		No.	Rate									No.	Rate
	Ploughing																	
	Digging of pits																	
	Sowing																	
	Nursery raising																	
	Transplanting																	
	Manuring																	
	Fertilizer application																	
	Irrigation																	
	Filling of pits																	
	Weeding																	
	Pruning and debudding																	
	Spraying of chemical																	
	Thinning																	
	Cutting																	
	Transportation																	
	Others																	

**Appendix – XI : Contd..**

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**B. Material cost**

Sl.No.	Material	Quantity	Rate	Value	Area covered
1.	Seed				
2.	FYM				
3.	Green manure				
4.	Fertilizer				
	Urea				
	DAP				
	SSP				
	MoP				
	Others				
5.	Plant protection chemicals				
6.	Irrigation				
7.	Others				

**C. Production and Sale**

Particular	House hold use	Quantity produced	Quantity sold	Rate	Total returns	Remarks
Main product						
By product						
Intercrop main product						
Intercrop by product						



## Appendix – XI : Contd..

Returns	Milch cows		Milch buffaloes	
	Local	Improved	Local	Improved
Total milk production per day (litres)				
Lactation period (days)				
Price of milk (Rs./lt)				
Value of manure (Rs.)				
Value of calves (Rs.)				
Others				
Total Gross returns (Rs.)				
Net returns over variable cost				

#Maximum/Minimum no. of livestock he would necessarily like to maintain  
(Predetermined Livestock activities)

Kind of Livestock	Max. No.	Mini. No.	Area needed for fodder growing
<b>Milch cows</b>			
• Local			
• Improved			
<b>Milch buffaloes</b>			
• Local			
• Improved			
Poultry birds			
Piggery			
Sheep			
Goats			
Bullocks			

**18. Production System Constraints****A. Technical Constraints**

Fragmented lands :

Non availability of recommended variety in required amount :

Poor quality of plant material :

Lack of technical know how :

Susceptible to insectpests and diseases :

High cost / Lack of money :

Low yielder :

Complicated practice / cumbersome :

Paucity of labour/ Higher cost of labour charges :

High cost of inorganic fertilizer :

Lack of irrigation facility :

Closing of canal during peak period :

Higher irrigation charges :

Lack of knowledge for applying fertilizer/insecticides/Herbicides :

Lack of knowledge about appropriate pruning :

Watchward and maintenance is complicated :

**B. Constraints to Agroforestry intercropping system :**

Complications in planting/sowing :

Waterlogging situation during planting season :

Complication in intercultural operation :

Uneasiness in application of plant protection measures :

Difficulty in harvesting of intercrops :

Suppression of main crop due to intercrop :

Damage of root system :

Not control over weeds :

**C. Socio Economic constraints :**

Hazards of wild animals in initial stages :

Lack of credit facility :

Problem of procuring the desired amount of loan :

Loan available but at high rate of interest :

**Appendix – XI : Contd..**

High cost of input :

Problem of theft/uprooting of five of plants :

Inadequate power supply :

Poor linkage with extension agency :

Lack of transport :

Any other reason :

**Marketing constraints :**

Over production in the area hence low price of product

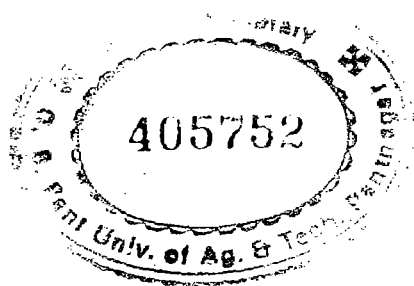
Undeveloped markets for sale of product :

Lack of knowledge about marketing agencies :

No of intermediaries quite large :

Lack of guarantee of disposing trees of maturity :

Lack of infrastructure (transport/road/nearness of sale point means ):

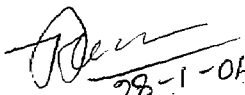


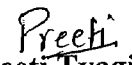
# ABSTRACT

<b>Name</b>	<b>Preeti Tyagi</b>	<b>Degree Programme</b>	<b>Ph.D</b>
<b>Id.No.</b>	25749	<b>Major</b>	Agricultural Economics
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Thesis title: **RESOURCE USE EFFICIENCY AND OPTIMIZATION OF FARMING SYSTEMS INVOLVING AGROFORESTRY IN THE PLAINS OF KUMAON REGION.**

Growing need of timber, fuel, environmental protection and sustainable land use planning has attracted planners, policy makers and researchers throughout the country. Agro forestry can be a potential mean to cater to the needs of forest-based industries and to develop the income generating and sustainable land use system. The present study was undertaken with the objectives viz. to identify the important farming systems involving agro forestry in the plains of Kumaon region, to work out their economics, to examine their resource use efficiency, to develop optimum plans for these farming systems and to study the constraints related to adoption of agro forestry. The data were collected both from primary and secondary sources. A number of 133 sample farmers were selected from the village development circles of Rudrapur and Haldwani block. The stream of costs and returns from different activities taken in different farming systems involving agro forestry were calculated. Cobb-Douglas production function was fitted to estimate the resource use efficiency of the identified farming systems. Linear programming technique to develop optimum plans and descriptive statistics to examine different constraints in the adoption of agroforestry were used. The empirical findings suggested that the major farming systems involving agroforestry in the study area was crop + poplar in block + livestock. This was the most rewarding farming system in terms of net income per farm as well as net income per hectare, both in existing situation and optimum plan. In existing situation crop + poplar in boundary + livestock farming system was generating maximum employment per hectare but among optimum farm plans crop + poplar in block + livestock farming system emerged out to be the maximum employment generating one too. Quantity of DAP & expenditure on seed materials were the most important determinants of increase in gross farm income, therefore the quality and timely availability of these inputs need to be regulated. Addition of milch animals to the farm can enhance the possibility of increasing farm income, employment and nutritional security to great extent. There is need of rational use of some under utilized resources like, human labour, irrigation and DAP, per hectare. Optimal plans developed for the farming systems involving poplar in block did not show a preference of the activity of poplar in block. Over all there existed a vast scope of increasing income in this farming system by reallocation of land, labour and capital. Farming systems involving poplar in boundary activity revealed the preference towards boundary poplar under optimal plans. The area under this activity increased up to the maximum permissible limit. The major problems farmers were facing in adoption of poplar were the incidence of pests and diseases on the poplar trees and the lower price of poplar due to glut in its production, There is need to develop remunerative price policies, contract farming system and suitable institutional frame work for promoting agroforestry in the study area.

  
28-1-04  
(Jagdish Kumar)  
Advisor

  
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## VITA

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- 2000 : Joined Ph.D Degree programme with major in Agricultural Economics at G.B.P.U.A&T, Pantnagar.
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