ASSESSMENT OF THE IDRC-SUPPORTED PROJECTS ON AGROFORESTRY AT NRCAF AND SILVIPASTURE AT IGFRI AT JHANSI, UTTAR PRADESH, INDIA

A CONSULTANCY REPORT

TO

THE INTERNATIONAL DEVELOPMENT RESEARCH CENTRE

SOUTH ASIA REGIONAL OFFICE, NEW DELHI, INDIA

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Our thanks are also due to the Directors, scientists and staff of NRCAF and IGFRI, who made excellent arrangements for our stay at Jhansi and extended all possible help in the supply of information as well as organizing the field visits to the on-station and on-farm trial sites. Our special thanks are also due to Dr R Deb Roy of NRCAF and Dr S Pathak of IGFRI without whose assistance we would not have been able to complete our job succesfully.

EXECUTIVE SUMMARY

This consultancy report is based on the study of annual reports, copies of which were made available to the consultants, and personal discussions with concerned scientists and participating farmers.

A. AGROFORESTRY

The International Development Research Centre (IDRC) sponsored a project on Agroforestry at the National Research Centre for Agroforestry (NRCAF) from June 1989. The objectives of this Project were to develop and test agroforestry technologies for increasing the productivity and sustainability of farming systems to improve the livelihood of the inhabitants of the Bundelkhand region. More specifically,the project involved diagnosing, designing, adopting and testing agroforestry technologies under farmers' conditions, disseminating these technologies through the extension infrastructure and strengthening the scientific capability of the All-India Co-ordinated Research Project on Agroforestry.

The NRCAF was established by apportioning some of the research and extension education responsibilities of the Indian Grassland and Forage Research Institute (IGFRI). The Centre is still in the formative stage with a limited number of research scientists and supporting technical, administrative and other staff.

A large number of on-farm and on-station trials have been undertaken involving multi purpose trees species, (MPTs), fruit trees and field crops.

The on-farm trials undertaken are of 4 categories, viz. (i) Agri-horticultural studies under partially irrigated condition, (ii) MPTs for boundary plantation, (iii) Agri-horti-silvicultural studies, and (iv) improvement of naturally growing *zarberi (Ziziphus nummularia)*, through *in situ* budding. The species identified for these trials are given below:

MPTs : Leucaena, eucalyptus, sissoo

Fruit trees : *Karonda*, pomegranate *(anar)*, amla, guava, ber, lime, sweet orange and Mandarin orange

Crops: Sesame *(til)*, groundnut, greengram *(moong)*, blackgram *(urd)*, maize, and soybean in kharif, and wheat and gram in rabi seasons.

On-station trials included MPTs for boundary plantation under rainfed/ partially irrigated conditions and Agri-horti-silvicultural studies similar to those conducted on-farm. Two more studies, viz. alley cropping and energy plantation under irrigated and rainfed conditions, were also conducted.

The species identified for on-station trials related to

MPTs : Leucaena, common sesban, acacia, Kassod tree, sissoo ,eucalyptus, neem,albizia and bamboo

Fruit trees : Citrus species

Crops : Sesame, groundnut, soybean, greengram and blackgram in kharif,and wheat and gram in rabi.

The on-station research by the centre alone or in collaboration with IGFRI envisaged (i) collection and evaluation of germplasm, (ii) screening of indigenous and exotic multi purpose tree species, and (iii) management trials on a few MPTs both under rainfed and irrigated conditions.

The trials conducted on the farmers' fields were similar to those conducted on on-station trials.

The Centre collected data in respect of trees and crops. However, no serious statistical analysis was attempted except working out averages on certain tree/crop parameters. The Centre possessed personal computers (PCs) as well as software. They were,therefore, advised to initiate the following analysis of data immediately.

i) Calculation of variability of estimates for tree/crop parameters.

ii) Inter-cropping analyses and variance analyses for the trials made on the basis of Randomized Block Designs(RBD).

iii) Regression models to work out relationships within the tree/crop characteristics like plant height and canopy/collar diameter and fruit yield.

iv) Negative effects of tree canopy on the crops.

v) Comparison of tree/crop parameters with control plots etc.

The Centre does not have statistical staff working with them. The

scientists here need to take up the analysis with the help of personal computers (PCs) and software available with them. However, it is doubtful whether all the possible information could be gathered and analysed without the attachment of a statistician for this purpose.

More detailed observations and recommendations are given at pages 14-16.

B. SILVIPASTURE

The IDRC sponsored a project on Silvipasture at the Indian Grassland and Fodder Research Institute (IGFRI), Jhansi in 1981. The Project is now in extended second phase. It envisages increasing the productivity of degraded grazing lands and wastelands in semi-arid pastoral areas by inter-planting fast-growing shurbs and trees with pasture legumes and grasses that have high potential for animal feed and firewood production. In the current phase the major emphasis is to test the effect of animal grazing, measure the effect of lopping on tree growths and biomass production, effect of protection on highly palatable species, performance of species in relation to existing micro-environments, and test the biological and economic feasibility of three-adapted silvipastoral models and measure their carrying capacities in on-farm conditions with the help of observations from the project. Efforts have been made to develop practical guidelines on the management of wastelands and natural range lands in the dry zone of India to attain sustainable silvipastoral system.

The silvipastoral system established at site I was evaluated for mixed grazing of 12 breedable ewes, 12 breedable does and 6 growing heifers. The lactating cows and half the number of sheep and goats were given supplementary concentrate feed in addition to conserved forage from the grazing area.

By the time grazing studies were undertaken the pastures were overtaken by dominant native grasses (*sedwa* and spear grass). Except from July to October the cattle required supplementary concentrate feed. The performance with respect to growth, reproduction, milk production and survival was satisfactory. The performance of sheep and goats with respect to production, growth and survival was also satisfactory. Since most livestock species in tropics breed throughout the year, the manipulation of their breeding so as to have their freshening coincide with the availability

of maximum feed resources will help in maximizing their production without supplementary feeding from outside the system.

Lopping in the present experiment was restricted to twice-a-year and that too for a limited period. Lopping should be done so as to extend the availability of feed for the longest period. Similarly, breeding should be organized such that the maximum demand on feed is, when it is readily available.

Social costs and benefits

In the hinter land of the study area an attempt was made to estimate the direct/ indirect benefits to the farmers of large investments made on the development of the silvipasture technology.

Direct benefits

The Internal Rate of Return (IRR) for different land terrains, viz. site I (undulated terrain with soil pH 6.89-7.69), site II (eroded plain with soil pH 6.38-7.28) and site III (ravine calcareous soil with pH 8.12-9.82), and for different alternate trials with tree spacings of 4 m x 3 m, 4m x 4m and 4 mx 6 m, as worked out for the project are given below.

(IRR%)

Tree spacings (m)	Site I		Site II		Site III	
	A	B	A	B	A	B
4x3	10	24	14	23	22	26
4x4	5	24	9	22	18	23
4x6	3	17	7	23	4	17

A: Institutional management.

B: Farmer management.

Note : The IRRs given above are tentative and indicative of the size. They, however, need further probe on the costs and benefits of the Project.

The IRR values for site III were generally higher than at the other two sites. Yet the farmers might prefer the technologies at sites I and II since the

returns start accruing here from the very end of the first year.

The average Net Present Value of Net Benefits (NPVNB) of the expenditure by the farmer during the period of 12 years, at the opportunity cost of capital of 15 % worked out to Rs 4,123, Rs 5,166 and Rs 7,933 for sites I, II, and III respectively. On an average NPVNB appreciation worked out to be Rs 472 per year.

From this analysis it may be said that the total cost of technology development (IDRC support plus ICAR matching grant) would be returned to the community if the technology is successfully implemented on a land of about 17,000 ha. Any participation higher than that would give returns higher than the investment, at 15 % opportunity cost of capital.

Indirect benefits

Regional development

The technology, if utilized and implemented on areas under different types of degraded lands in the country, can take care of the increasing load of grazing animals on forage, and food and fuel for people.

Land productivity

Adoption of this technology would raise land productivity by about 8-10 times (forage, fire wood and small timber) and the quality or nutritive value of output by about 7 times. Thus, the production of forage, firewood and small timber *in situ* would help prevent large-scale animal migration and forest destruction, besides helping conservation of soil, water, nutrients and biodiversity.

Employment generation

The establishment and management of silvipastures can generate, in an average of 10 years cycle, 120 man days of employment per hectare per year.It means that if the programme is extended, say, on 10 million ha of land, it can provide employment to about 5 million people annually on agriculture and on allied ancillary activities.

Environmental gains

The silvipasture programme reduces soil loss from 17.78 t/ha a year under bare soil to 1.26 t/ha a year. The improved infiltration rates will enrich the underground streams to improve the irrigation and drinking water resources.

DATA ANALYSIS

While Randomized Block Design (RBD) and Split plot techniques were used for the experiments in the fields for on-farm/on-station trials, no serious statistical analysis was attempted. During the remaining period of the Project the collected data on the various parameters of the programme be consolidated and statistical analysis of the data be attempted.

It was also suggested that they work out seasonal indices for the grass and tree yields so that efficient lopping management systems could be developed for optimal use of fodder in a sustainable manner.

INTRODUCTION

This Report presents the Consultants' assessment of the progress of work and the evaluation of the IDRC-supported projects on (i) Agroforestry at the National Research Centre for Agroforestry (NRCAF) and (ii) the Silvipasture Project at the Indian Grassland and Fodder Research Institute (IGFRI), of the Indian Council of Agricultural Research (ICAR) at Jhansi, Uttar Pradesh.

The terms of reference of the assignment were to:

(a) visit the Centre-supported projects on Agroforestry at NRCAF, Jhansi, and Silvipasture at the IGFRI;

(b) review the work accomplished to-date in the Agroforestry (India) project, and to assist with the methodology and plan of work for the remainder of the project duration;

(c) advice the Agroforestry (India) project staff in the analysis of data generated up to date;

(d) evaluate the achievements/activities of the Silvipasture Project with particular reference to the transfer of technology and extension of project findings to the user groups, i.e, farmers, NGOs, government agencies, etc.;

(e) review and assess the technical content of the reports and other publications from the two projects; and

(f) prepare a social cost-benefit analysis of the Silvipasture Project up to date.

The two organizations were visited during 1-8 September 1994. The itinerary comprised on-farm and on-station site visits and meetings of the Consultants with the staff of the two projects (Appendix I). To understand and appreciate the impact assessment of the projects,the Consultants discussed with the farmers on whose sites the on-farm trials were undertaken and with the farmers in their neighbourhood. They also held discussions with officers of the Development Alternatives, a voluntary organization and the officers of the Forest Department where the IGFRI has taken up large-scale demonstration/testing of technologies related to silvipasture.

The assessment of the Consultants on Agroforestry and Silvipasture programmes are presented in section A and Section B of the report respectively.

SECTION A

AGROFORESTRY PROJECT

1.OBJECTIVES

(a) General Objective

To develop and test agroforestry technologies to increase the productivity and sustainability of farming system with a view to improving the livelihood of the inhabitants of the Bundelkhand Region of Uttar Pradesh, India.

(b) Specific objectives

(i) Diagnose the existing farming system constraints and design agroforestry intervention to address the same;

(ii) Develop, adapt and test agroforestry technologies in farmers' conditions;

(iii) Disseminate agroforestry research results for use in extension and development programmes in the area; and

(iv) Strengthen and support the specific activity of the All-India Co-ordinated Research Project in Agroforestry.

2.WORK DONE ON THE OBJECTIVES

b (i) To diagnose the existing farming system constraints and design agroforestry intervention to address them

No Diagnosis and Design (D & D) exercises have been separately undertaken by NRCAF under the IDRC-supported projects on Agroforestry. However, a D & D exercise was conducted under the ICAR /ICRAF collaboration in 3 selected villages, viz. Lakara, Karari and Rudrakarari, in Jhansi district in March 1989, under the Agroforestry Research Proposals for the Lakara-Karari-Rudrakarari watershed area. In this study, 2 scientists from ICRAF joined in the field work along with some scientists from IGFRI and 1 officer from ICAR, besides the Director, NRCAF.

This report was utilized for this programme. The Project personnel felt, and rightly so, that repetition of a D & D again may not be necessary, particularly since the results related to a very recent period, i.e. 1989.

b(ii) To develop, adapt and test agroforestry technologies in farmers' conditions

A detailed list of on-farm and on-station trials made under IDRC Agroforestry Project is given at Appendix II. Salient findings of these trials up to 1993-94 are given below. A list of botanical names of MPTs, fruit trees and grain crops used in the report is given at Appendix III.

All agroforestry technologies are developed to improve the productivity of farming systems and consequently the livelihood of the inhabitants in the Bundelkhand region by meeting the fodder requirements for their animals in addition to their requirements from their fields.

On-farm trials

On-farm trials were conducted on 7 farmers' fields (in 3 villages) covering a total area of 3.83 ha. Trials with 2-3 farmers are earmarked for 1994-95.

The species identified for these trials are:

MPTs : Leucaena, eucalyptus, sissoo.

Fruit trees : *Karonda*, pomegranate *(anar)*, amla, guava, ber, lime, sweet orange and Mandarin orange.

Crops: Sesame *(til)*, groundnut, greengram *(moong)*, blackgram *(urd)*, maize, and soybean in kharif, and wheat and gram in rabi seasons.

The on-farm trials undertaken are of 4 categories, viz. (i) Agri-horticultural studies under partially irrigated condition, (ii) MPTs for boundary plantation, (iii) Agri-horti-silvicultural studies, and (iv) improvement of naturally growing *zarberi (Ziziphus nummularia)* through *in situ* budding. Work done on these trials is briefly given below.

i) Agri-horticultural studies under partially irrigated condition

The objective of this trial is to determine the most suitable combination of fruit trees and crops to maximize production.

During 1989-90, in anticipation of approval of the Project, trial was laid out in one farm in RBD with 3 fruit trees, viz, guava, ber and citrus (lime), and 5 wheat-based crop rotations, viz. fallow-wheat, maize-wheat, greengram-wheat, groundnut-wheat and blackgram-wheat, replicated 2 times. Fruit trees were spaced at 6 m x 6 m. Crop yields of different crops grown in interspaces and growth of fruit trees were recorded.

On an average, a slightly higher plant height, canopy diameter and collar diameter were observed when fruit trees were grown with crop rotation of groundnut-wheat, greengram-wheat and blackgram-wheat. There was practically not much difference on wheat production with fruit tree association.

Another trial with 4 fruit trees, viz. guava, Mandarin orange, ber, and pomegranate, and 2 crop rotations with blackgram-wheat and greengram-wheat with 3 replications in RBD was conducted during 1992-93. The fruit trees were spaced at 6 m x 6 m.

This trial showed that, in general, the production of wheat in black-gram-wheat rotation was higher than in groundnut-wheat rotation.

A third trial was also made during 1993-94 with guava, amla and pomegranate, with wheat-based crop rotations, viz. groundnut-wheat, greengram-wheat and blackgram-wheat, in RBD, replicating thrice.

A study on ber-based agri-horticulture was also undertaken during this year.

The wheat production in all these trials varied from 3.56 tonnes/ha in association with pomegranate to 3.78 tonnes/ha in association with ber. The results need further critical analysis.

ii) MPTs for boundary plantation

The objective of this trial is to study the effect of MPTs on crop productivity.

During 1993-94, 2 MPTs, viz. eucalyptus and leucaena, were planted on the boundary of farmers' fields. Safeda and subabul were slightly tall when planted in East-West direction than North-South direction. The maximum grain yield of gram (0.85 t/ha) was recorded from the North-South direction in both the boundary plantations.

A second trial with MPTs like sissoo and *karonda* (fruit shrubs) was at-

tempted during 1991-92. The plant heights of sissoo and *karonda* were slightly higher in East-West direction than in North-South direction. The maximum grain production of 4.10 t/ha was recorded with South-East direction followed by North-East direction with a production of 3.90 t/ha. The production of gram in the central plot was 3.50 t/ha.

iii) Agri-horti-silvicultural studies

One trial comprising 3 citrus species, viz. lime, Mandarin orange and sweet orange, with 2 crop rotations, viz. greengram bean-wheat and blackgram bean-chickpea, with 4 replications in RBD was undertaken during 1991-92 at village Bhatagaon. Fruit trees were spaced at 6 m x 6 m. Leucaena was planted on the field boundaries. Growth of fruit trees was recorded every 6 months.

On an average, the plant height, collar diameter and canopy diameter of fruit trees were slightly higher where blackgram-gram crop rotation was followed than with blackgram-wheat crop rotation.

During rabi 1991-92 blackgram-wheat rotation gave maximum crop production (5.21 and 4.01 t/ha respectively) from the interspaces of sweet orange; in blackgram-gram crop rotation the maximum grain yield was 0.90 and 1.41 t/ha, respectively, from the interspaces of Mandarin orange.

During 1993-94 the mean production of wheat was 3.10 t and of gram 0.65 t/ha. There was practically no significant variation in the production of wheat and gram from the first, second and third rows from the trees. However, production of gram in association with sweet orange was comparatively lower than with Mandarin orange and lime.

Leucaena planted on field boundaries were repeatedly lopped, and this provided leaf fodder and fuel wood to the farmer.

In a second trial, a guava-based study was initiated during 1994-95 on a lady farmer's field at Karari, with 8 tree treatments and 3 replications in RBD. The treatment combinations comprised: (i) guava alone, (ii) guava+leucaena, (iii) guava+greengram-wheat, (iv) guava+maize-gram,(v) guava+leucaena+maize-gram,(vi) guava + leucaena + greengram-wheat, (vii) pure gram-wheat, and (viii) pure maize-gram.

A third trial, which was citrus-based, was also attempted during 1994-95 with 5 treatment combinations, viz. (i) citrus alone, (ii) citrus+leucaena, (iii) citrus+groundnut-wheat, (iv) citrus+leucaena+groundnut-wheat, and

(v) pure groundnut-wheat in a RBD with 4 replications. Plantation of citrus and leucaena was carried out during the fourth week of August 1994.

It is too early to get the results of these 2 trials.

iv) Improvement of naturally growing zharberi *through* in situ *budding*

During 1993-94, a trial on the improvement of naturally growing *zharberi* through *in situ* budding of improved variety of ber, viz. 'Banarasi Karakai', was initiated in a farmer's field in village Ambabai. Budding was successful in 30 to 40 %. This was considered quite satisfactory in the wastelands. The information on growth and fruit production will be recorded during 1994-95.

On-station trials

The on-station trials conducted by the Centre included MPTs for boundary plantation under rainfed/partially irrigated conditions,and (ii) agri-horti-silvicultural studies as conducted under on-farm trials. Two more studies one on alley cropping system and another on energy planting in irrigated and rainfed conditions were conducted.

The species identified for on-station trials related to

MPTs : Leucaena, acacia, Kassod tree,sissoo, eucalyptus, neem, albizia and bamboo.

Fruit trees : Citrus species

Crops : Sesame, groundnut, soybean, greengram and blackgram in kharif, and wheat and gram in rabi.

Before conducting the on-station trials, the area was covered with natural denuded grasslands along with unwanted bushes and trees.

i) MPTs for boundary plantation under rainfed/partially irrigated condition

The objective of this trial is to study the land productivity by introducing MPTs for producing small timber, fuel and fodder on field boundaries. The trees have been planted in North-South and East-West directions.

In one trial 2 MPTs, viz.Israeli babul and leucaena, were planted during 1989-90 around all the 4 boundaries of typical marginal agricultural land on the Central Research Farm of the NRCAF, Jhansi. Inside the field sesame

was raised during kharif under rainfed condition. Growth data of the trees was recorded at 6 months interval.

Growth data of Israeli babul and leucaena recorded in December 1993 revealed that maximum height of 8.60 and 5.80 m was reached in leucaena and Israeli babul, respectively, when grown in South-West direction. The maximum collar diameter was 25.3 cm and 13.7 cm, respectively, with leucaena and Israeli babul in East-West direction. Canopy and dbh diameter were higher in both the MPTs grown in South-West direction.

Pruning of trees up to 50% height revealed that higher fuel wood and dry leaf fodder were obtained when MPTs were grown in East-West direction.

Sesame grain yield during 1991-92 and 1992-93 was maximum (0.79 t/ha) with MPTs in North-South and East-West directions (0.39 t/ha), with a relative grain yield of 86 and 78% respectively. During 1993 (kharif) production of sesame was higher (0.42 t/ha) from North-West direction compared to those from other directions.

In the second case a trial similar to the one conducted for on-farm plantation under rainfed condition was initiated by planting along the boundaries Israeli babul and leucaena 2 m apart. The study was conducted at the Central Research Farm of NRCAF, Jhansi under partially irrigated condition during 1989-90. Groundnut-wheat crop was taken in the field. Growth parameters of MPTs were recorded at 6 monthly intervals during 1992-93. MPTs were pruned to yield green fodder/green manure and fuelwood.

Leucaena and Israeli babul attained maximum height of 9.6 m and 6.9 m, respectively, when grown in North-South direction. In leucaena collar diameter (20.6 cm), dbh (14.8 cm) and canopy diameter (5.6 cm) were higher when trees were grown in North-South direction.

In Israeli babul collar and canopy diameters and dbh were higher (14.2, 12.2, 6.1cm respectively)when grown in North-South direction.

Pruning of MPTs up to 50% height revealed that maximum fuel wood (7.05 kg/plant) and dry leaf fodder (12.15 kg/plant) were recorded with leucaena when grown in South-West direction. In Israeli babul maximum fuel wood (4.08 kg/tree) and dry leaf fodder (0.33 kg/tree) were recorded from South-West direction.

In the third farm, during 1993-94, 5 MPTs, viz.babul acacia,Isareli babul, East Indian walnut, *khejri* and neem, saplings were planted at 5 m x 8 m spacing with 4 replications in a typical red gravelly soil with small pebbles.

The results are yet to be studied.

ii) Agri-horti-silvicultural studies

During 1993-94 an agri-horti-silvicultural trial was initiated with 8 treatment combinations consisting of lime alone, lime + sesame (oilseed), lime+greengram (foodgrain), lime+clusterbean (vegetable), lime+stylo in basin, pure crop of greengram, sesame alone and clusterbean alone. Leucaena as MPTs was planted in between citrus plants. Citrus and leucaena were planted in July 1993 while other treatments were imposed during August 1994.

Studies on the evaluation of 4 species of *Albizia*, viz. East Indian walnut, white siris, yellow siris and black siris, with and without crops was initiated during 1993-94 at the Central Research Farm under rainfed condition. Eight treatment combinations were laid out with 4 replications. The tree saplings were planted at 5 m x 5 m spacing.

Studies on the evaluation of *Acacia* species, viz. babul acacia, Israeli babul and *Ram kanti*, with and without crops under agri-silvicultural condition in rainfed situation was initiated during 1993-94 with 8 treatment combinations in RBD with 4 replications. Tree saplings were planted at 5 m x 5 m spacing. Sesame, as a field crop, was sown during July 1994 with treatments consisting of intercrops. One of the experimental sites was red gravelly with small pebbles and a typical wasteland often used by the farmers for arable farming.

During 1993-94 an intercropping trial on bamboo with 5 treatments consisting of bamboo alone, bamboo-soybean, bamboo-groundnut, groundnut alone and soybean alone was laid out in a RBD with 4 replications. The establishment of bamboo was quite good. Sowing of different crops was imposed during August 1994. Growth parameters of bamboo were recorded every 6 months.

During 1993-94 a trial on silver oak based agri-silvicultural trial with 7 treatment combinations consisting of silver oak alone, silver oak+maize-wheat, silver oak+groundnut-wheat, silver oak+maize-gram, silver

b (iii) Disseminate agroforestry research results for use in extension and development programmes in the area

Farmers' Days and *Kisan Gosthis* are being organized both in kharif and rabi seasons, i.e. during September and March, respectively, every year in which farmers from surrounding villages come and see the experiments and also raise questions relating to their problems for which suitable suggestions/solutions are given by various experts in different fields. In addition to this the Centre is also bringing out pamphlets and technical bulletins in local language for the said purpose.

The Centre has also been publishing news related to agroforestry technologies in local newspapers in Hindi, organizing open farm school in different villages, delivering radio and television talks on advanced technology of agroforestry, displaying charts, posters and video-films, and distributing high-yielding seeds and seedlings appropriate for agroforestry to the farmers.

More than 350 farmers of different villages have participated in field day programmes organized twice in a year. On these occasions farmers interact with specialists at the Centre on their problems like protection of trees against droughts, diseases etc.

b (iv) Strengthen and support the specific activity of All-India Co-ordinated Research Project on Agroforestry

In the research workers' meeting of All-India Co-ordinated Research Project on Agroforestry, this Centre participated as resource Institute and helped in monitoring evaluation and development of programmes on the basis of research results obtained by the Centre through its programmes. Scientists of AICRP are also invited to participate in the seminar/symposium/ conference organized by NRCAF.

3.DATA COLLECTION AND ANALYSIS

The statistical activities under the programme were examined with reference to: (i) whether the information collected meets the requirements to an adequate extent enabling application of statistical techniques to the experimental trials to draw valid conclusions, and (ii) the extent of such analysis undertaken for drawing conclusions.

Data collected

The data were collected under two categories : (a) Tree-based, and (b)

crop-based. Under the tree-based data, information was recorded in respect of parameters like (i) establishment/survival, (ii) plant height, (iii) collar diameter, (iv) canopy diameter, (v) diameter at breast height (dbh), (vi) pruning/pollarding of MPTs etc.

The crop-based information related to (i) plant population, (ii) plant height, (iii) number of tillers (in wheat only), (iv) number of effective tillers, (v) number of pods/plant, (vi) number of leaves/plant (in sesame-groundnut only), (vii) number of branches/plant (in sesame and groundnut only), (viii) grain yield, (ix) straw yield, and (x) test weight. The items of information and the frequency at which they are collected are given at Appendix IV.

Data collected on the above parameters are preserved in the form of registers or data sheets bunched together in the form of a file. They were advised to immediately initiate computerized data transfer and maintenance system.

Processing equipment

Two PCs, viz. PC-386 (without any provision for terminals) and PC-486 (with provision existing for 4 terminals), were procured under USAID programme. Standard PC software, viz. dBASE, LOTUS 123 Rel.3. SPSS/PC,SCAUF-20, word perfect and quattro Pro, is also available. This software provides wide range of processing capabilities such as regression, analysis of variance, generation of pie diagrams and graphs. Nevertheless, the software available is of general purpose in nature which the scientists in the centre have not so far made use of for statistical analysis of data.

Data analysis

With the availability of personal computers, it is expected that the analysis of experimental data should have been undertaken. However, no serious statistical analysis of data, except working out averages, has been attempted at the Centre.

The studies of interest in the agroforestry involve assessment of different tree species regarding their suitability in an environment, compatibility of different tree species with different agricultural crops etc.

After detailed discussions with the Director and other scientists of this Centre, on the analysis of data, the Centre was advised to initiate the following statistical analysis for improving the information content of the programme.

Variability of estimates

At present the data collected on trees and crops are used only to estimate the averages of: (i) grain yields in respect of crops grown in kharif and rabi seasons, (ii) tree yields, and (iii) plant parameters (like height, collar diameter etc). However, the value of any estimate, particularly the averages, without any indication of its variability is very low. As such, along with estimates like means of plant parameters the Centre was advised to work out the standard errors of the estimates.

Variance analysis for the RBD experiments

The design adopted for experiments in the fields on on-farm and on-station trials during the last 3 years was RBD with a combination of trees and crops. Each experiment is replicated generally 2/3 times to determine the differences in yields among plots treated alike and to estimate experimental errors.

These designs were adopted on the advice of the statistician who was working at that time in IGFRI. However, no analysis has so far been undertaken of the results. The Centre was advised to attempt mean comparison of intercropping and analysis of variances on the basis of data collected by the centre on crops and trees, to arrive at

- variation in the yield in specific species under different crop combinations
- effect of spacing of trees on the yields of different crops
- effect of tree combinations on the yields of different crops
- effect of boundary plantation on the yield of crops
- estimates of experimental error variance
- fruit bearing comparison between intercropping and control.

It is also sensible to have separate analysis of data in respect of crop-tree mixed trials with (i) the sole crop plot data of each crop, and (ii) the sole tree plot data in respect of each tree species.

In these experiments one problem, however, arises about the comparability of yield between the 'tree treatments'. Since the trees are heterogenous, the yields are not comparable unless they are converted into standard values.

The Consultants discussed this aspect with the statisticians at IASRI. They were informed that scientists are working on this aspect, They also opined that value could be taken in this regard for purposes of comparisons.

Crop-growth models

Yield performance of trees/crops is a product of several tree/crop and non-tree/non-crop characteristics. All of them are measured simultaneously and a study of their association with each other can provide useful information about how the treatments influenced tree/crop response. Regression analysis allows such a study. For example, volume of timber may be correlated with dbh of trees. Similarly, relationships can also be established between (i) plant height and canopy diameter/collar diameter, (ii) canopy diameter and fruit yields etc.

By using the cross-section data in respect of trees for each year, regression relationships could be established with fruit yield as a function of dbh and other growth parameters. This would ultimately enable predication of the fruit yield of different species.

The Centre was advised to undertake such regression studies.

Other studies

At present, data are recorded in respect of crop yields of the 1st, 3rd and 5th rows to study the effects of shading of trees.

Studies have also been suggested using the data on growth, yield, etc. of the crop under the canopy within various radial distances to analyse the negative effects of tree canopy on the crops. The biomass variation surrounding the tree at regular intervals during one crop season may be obtained and incorporated into crop-growth model. The results obtained would help in assessing the stage of crop growth which becomes critical due to shading. This may be attempted for a few cases on a selective basis.

A study of relative growth of tree parameters like dbh, height, percentage of disease affected, etc. at a particular age can be undertaken on different fields on-farm/ on-station compared to the control plots.

It is however doubtful whether all the possible information could be gathered and analyzed without the attachment of a statistician for this purpose. The scientists themselves may not be able to undertake these jobs in addition to their normal duties. However, they have been advised to

undertake the analysis with the use of computer systems available with the Centre. Periodic guidance on the data analysis is also necessary.

4.OBSERVATIONS AND RECOMMENDATIONS

Organizational aspects

Since the commencement of Agroforestry Project, the NCRAF deployed 1 Principal Investigator, 3 Technical Assistants and 1 Assistant, besides other secretariat staff comprising 1 secretary , 2 drivers and 3 watchmen. Among them 2 scientists were trained in Agroforestry work. The staff work under the overall supervision of the Director.

The staff support to the project appears to be inadequate. According to the Director of the Centre, 1 Scientist (Horticulture), 1 Scientist (Socio-economics), 1 Scientist (Soil Science), and 1 Technical Assistant (Statistics) would be the minimum additional requirement for covering all aspects of the trials.

The Centre may take action on this aspect.

Technology Development

a) In the Project proposal on Agroforestry document No (3-p-89-0051) of IDRC, a copy of which was provided to the consultants, on Page 6 under objective (b)-Technology Development, it was mentioned under on-station

"Collection of local germplasm and its evaluation including species utilized by farmers in their current systems (after review of germplasms collected at IGFRI/NRCAF to avoid duplication) --------- "

Both IGFRI and NRCAF informed that no such co-ordinated research is envisaged. This may be sorted out and appropriate studies taken up.

b) the same document mentioned on Page 7, para 46 under objective (d)-strengthening scientific capabilities, it was stated

"one of the mandates on NRCAF is to provide training on agroforestry systems and produce research guideline for the 31 co-ordinated centres of AICRPAF --------"

It appears that a post of Project Co-ordinator has been provided under the VIII Plan, but it is yet to be created and filled. This is not allowing any serious interaction between NRCAF and the centres of activity.

On-farm trials

a) The on-farm trials undertaken by the Centre look similar to the on-station trials except that one set is undertaken on farmers' fields and the other set on the Centre's fields.

In agroforestry, the major interest is normally on increasing the yield of crops with some fruit, timber or fuel-cum-fodder trees planted in a manner that the timber/ fuel/ top feed requirements of the farmers are met without any serious adverse effect on field crop production. Thus, the agroforestry system should aim at growing tree species with arable crops on the same land for ensuring positive synergism. The number of trees introduced on the land should therefore be small so that they do not have adverse effect on the yield of crops. Particularly since a majority of farmers in this region fall in the group of small and marginal category with subsistence cropping practices, the system of introducing small number of trees along with normal crop may be suitable to this group of farmers and readily acceptable by them.

b) To encourage participation of farmers in the agroforestry programme, at initial stage, the Centre was providing them improved varieties of tree saplings of MPTs including fruit trees, seed of grain crops, fertilizer, pesticides etc.

However during the field visits of the Consultants, it was observed that the Senior Scientist who was incharge of this Programme till recently was, providing free labour also to work in their fields. The farmers are continuing to demand the same. The Centre has now pleaded that the farmers should provide their own labour. This step of the Centre looks correct since the objective of the programme is not to take over all the field operations on the farm. Involvement of farmers is an absolute necessity.

c) The farmers on whose lands the on-farm trials are currently conducted preferred fruit trees in the fields and MPTs on bunds/boundaries. Their interest appears to be to convert their farms into horticulture farms. During the visits to the fields, it was observed that intercropping was either sparce or not there. The reasons provided for the thinly scattered crop was not satisfactory. The only explanation provided was that the sowing was taken up very late. However , the fact appears to be that most of the farmers who have currently undertaken these trials were interested in converting their farms into Horticulture farms. These farmers may be medium or upper medium class of farmers.

4.06

The on-farm trials may also be taken up in small farmers' fields and made attractive to them. They would prefer to obtain fuel, fodder, small timber, fruits as well as grain from the same piece of land.

Socio-economic studies

Socio-economic studies may be conducted periodically in the villages falling within the hinterland to ascertain the agroforestry preferences of marginal/small farmers whose land holding is less than 1 ha (in this area more than 90 % households have less than 1 ha of land).

This information could also be collected in a suitable format from the farmers attending *Kisan Gosthis* and Farmers' days.

Data collection/analysis

No serious statistical analysis of data except working out averages has been attempted at the Centre even though personal computers as well as standard software are available. Since the interest of agroforestry trials is intra-alia, to see how the crop/tree perform under different treatments, the Centre should attempt analysis of these data.

Analysis of all the trials which have completed more than 3 years should be started immediately. Based on this, critical reviews be made for any mid-term corrections if necessary.

SECTION B

SILVIPASTURE PROJECT

1.OBJECTIVES

(a) General objective

The general objective of the project is to increase the productivity of degraded grazing lands and wastelands in semi-arid pastoral areas by interplanting fast-growing shrubs and trees with pasture legumes and grasses that have high potential for animal feed and firewood production.

(b) Specific objectives

The specific objectives of the project are to:

(i) test the effect of animal grazing on silvipastoral system established in the previous phase;

(ii) measure the effects of lopping on tree growth and biomass production on the existing experimental sites;

(iii) study the effect of fencing to protect highly palatable species;

(iv) analyze and monitor the species performance in relation to existing micro-environments; and

(v) test the biological and economic feasibility of the 3 adapted silvipastoral models, and measure their carrying capacity under "on-farm" conditions.

2. WORK DONE ON THE OBJECTIVES (EVIS-4.61)

b (i) To test the effect of animal grazing on silvipastoral system established in the previous phase

The silvipastoral system established at site I was evaluated by grazing a mixed group of cattle, sheep and goats for the effect of grazing on silvipastoral system established in the previous phase. The 10 ha area was divided into 6 compartments. One compartment was reserved for hay making. During November and December, and May and June lopped fodder from trees was offered to the animals. Grass hay was supplemented to cattle

during April to June.

At the site, on 23 August 1989, 12 breedable Muzzafarnagri ewes and 12 breedable Barbari does were introduced, and on 1 October 1989, 6 growing Tharparkar heifers of about 9 months of age and weighing on an average 72.67±4.89 kg were introduced. The growing heifers were maintained on grazing alone from July to October without any supplementary feeding. The animals were supplemented with concentrates @ 1% of their body weight from November onwards till the onset of monsoon. When they came in milk they were supplemented with concentrate @1 kg for the first 4 kg of milk during July to October and onwards, 1 kg for maintenance and 1 kg for every extra 2.5 kg of milk produced. Out of 12 ewes 6 were supplemented with concentrate @ 250 g/ animal a day. Similarly 6 does were given concentrate @ 250 g/animal a day.

Effect of grazing on yield and quality of forage

The response of tree species to grazing varied. In the case of Israeli babul the growth depression due to grazing was 23, 19 and 29%, respectively, in height, collar diameter and dbh during 5 years. While in the case of leucaena plots due to grazing the growth improved by 19 and 11%, respectively, in collar diameter and dbh. It appears that the twin effects of soil compaction and the removal of competition from grasses were the factors responsible for the above two responses.

At the close of 4 years of grazing, there was maximum standing biomass in the control plots (no tree) and the minimum in leucaena plots. Maximum standing grass biomass was with *anjun*. Compared to the yield at the start of the experiments there was a slight decline in the peak yield of the control plots. But the trend in the variation remained the same.

With grazing and increasing shade, production of grasses under leucaena declined. This is because of the domination of the weed species, allelopathic effect of the tree leaves, and maximum animal trampling and pressure under trees where animals flocked for shade during hot days. There was hardly any difference over the years in the peak biomass except the annual variation in participation affected yields. In the renovated pasture, shade of trees reduced forage production in general. Maximum production was in the control plots (without trees). Bunch grass continued to produce more under all the situations showing high adaptability even to intense shade. Although this produced more than guineagrass considering

the utilization of forage by animals, guineagrass, proved to be beneficial for silvipastoral systems. Thus, at the end of this phase, these pastures continued to yield over 6-7 t/ha.

Forage quality

The dominant grass species at the site,viz. sehima and spear grass, were analyzed for their quality parameters during active growth period. The herbage contained 7 to 8% crude protein and had about 60% digestibility in middle of July. It decreased to 3 to 4% crude protein and 30 to 40% digestibility by middle of October.This clearly indicates that available forage from October onwards could not even provide the maintenance need of the animals. The lopped fodder from leucaena was most liked by all the animals, while lopped fodder from black siris was disliked by all the species. In-depth studies were also conducted to know the supplemental value of leucaena for growing and lactating animals in separate supplementary experiments. The leaves of *anjun* were quite liked by cattle, sheep and goats.

The productive and reproductive performance of the animals were as follows:

A. Cattle: Growing Tharparkar heifers gained, on an average, about 500 g/head a day including compensatory growth during monsoon (July to October) without any supplemental feeding. The concentrate supplementation of about 1% of the live weight during dry months led the animals to gain, on an average, about 100 kg live weight / animal a year. They conceived at the age of 34.87±1.71 months with an average live weight of about 280±5 kg.

Out of 6 heifers, 1 heifer died after 6 months. Therefore the observations recorded are based on 5 animals only. All the 5 heifers gave birth to calves weighing, on an average, 21.22±1.33 kg. Four animals completed first lactation and presently are in second lactation while 1 is still in first lactation. The average lactation length was 411±16.21 days. The first lactation yield was 1,925±36.84 kg, The total milk production was 10,772 kg during the project period, from May 1992 to June 1994. The intercalving period averaged 518±36.21 days. During the period 1 calf was auctioned . At present 5 cows and 8 calves are available.

B. Sheep: The total number of lambs born during the project period was 50. The breeding efficiency of sheep was 0.9 lamb / ewe a year. The

average birth weight of the lambs was 2.98±0.07 kg. Lambs born from July to December were heavier than those born from January to June. The average weight at weaning was 9.63±0.47 kg while the subsequent body weights at 6, 9 and 12 months were 15, 20 and 23 kg respectively. The mortality rate recorded in lambs was 26% up to 3 months of age. The mortality rate in adult sheep was 15%. During the project period 16 sheep were auctioned. At present 16 sheep are available. The total wool production during the project period was 71 kg.

C. Goats: The number of kids born during the period was 100. The breeding efficiency was 1.8 kids/doe a year.The average birth weight of goats was 1.12±0.03 kg.The kids born during July to December were heavier than those born during January to June. The average weight of weaning was 5.42±0.027 kg. The live weights at 6, 9 and 12 months of age were 8, 10 and 11 kg respectively. The mortality in kids and adult goats was 28% and 16% respectively. During the period 21 goats were auctioned; 23 goats are presently available.

b (ii) To measure the effects of lopping on tree growth and biomass production on the existing experimental sites

Lopping is a process of removing the twigs and leaves from the tree during the lean periods of availability of surface vegetation. The annual growth increments are thus partially utilized and exported from the system. Its impact on trees has been measured in their growth as reflected by increments of height, collar and breast diameter.

On site I under control (ungrazed) plots lopping reduced tree growth. In grazing plots lopping gave higher growth increments compared to control.

Effect of lopping

Over the period of 4 years the net change in growth parameters of tree species due to variable lopping intensity indicated variable response by the tree species. In Israeli babul and East Indian walnut the height growth increased on lopping with maximum at 50% lopping intensity. The collar diameter growth showed similar pattern as of height in leucaena and black siris, whereas in Israeli babul it showed decrease. In dbh all the 3 species showed decreased growth due to lopping. Thus lopping inversely affected the diameter growth.

In general, lopping intensity improved production per tree but due to variable tree spacing the production was more with higher density compared to that with lower density. Production per tree decreased over years in case of Israeli babul while in black siris and leucaena it increased. The increment was about 3 times in leucaena and 2.5 times in black siris. A decrease of 25% was observed in Israeli babul. The leaf-stem ratio was high in black siris followed by that in leucaena. Thus from production angle total biomass of 8.4 t/ha was produced by leucaena followed by 3.4 t/ha by black siris, 2.3 t/ha by *anjun* and 1.6 t/ha by Israeli babul. It showed the relative value of different species.

Effect of tree shading on micro-environment and yield attributes, and acceptable limits

The interaction of filtered light and canopy temperature on the morpho-physiology and productivity of grasses (*sedwa* and spear grass) was studied under the tree canopies of *anjun*, leucaena, Israeli babul, East Indian walnut and black siris. Israeli babul and *anjun* allowed 60% and 55% PAR infiltration, whereas leucaena filtered least amount of PAR (33%). The high canopy-air temperature difference (-6.8° C) was recorded under leucaena. The higher amount of chlorophyll (a+b) in grasses was observed under the tree canopies than in open field due to high amount of chl-b. The LAI and NAR of grasses were higher under the canopies of Israeli babul and *anjun*. About 98% of dry matter yield (DMY) of grasses was obtained under *anjun* and Israeli babul canopies when compared with the DMY of open field. The DMY was closely associated with the available PAR under tree canopies indicating that for optimum production of these grasses (*sedwa* and spear grass) about 60% of PAR is required.

The net photosynthesis, transpiration, productivity and other related parameters were studied in bunch grass and guinea grass under the tree canopies of 10-year-old leucaena and in open field during September-October in 1992 and 1993. The results showed that PAR and temperature were reduced under the canopies of leucaena. The rate of photosynthesis, transpiration, stomatal conductance, leaf temperature, and the ratio of photosynthesis with other parameters decreased in both the grasses under tree canopies as compared to those in open field. The high chlorophyll content (Chl-a and Chl-b) of these grasses was under tree canopies but maximum chl a:b was observed in bunch grass indicating its fast adaptation to low light intensity under leucaena. Bunch grass gave higher dry

matter yield and specific leaf weight ratio than guinea grass. The dry matter yield and other physiological parameters were significantly associated with available PAR under tree canopies.

The extent and amount of the effects of leucaena trees on productivity and adaptation of grasses can be explained by the physical and physiological influence. The grasses mainly depended on the light transmission through the tree canopies. According to the yield and physiological characteristics of grasses, large reduction was caused due to high shading degree. In order to have a more productive and sustainable silvipastoral system it is necessary to maintain an ideal canopy size for optimum PAR transmission by pruning and/or thinning the trees.

b(iii) To study the effect of fencing to protect highly palatable species

At site II black siris, East Indian walnut and leucaena were tried. Black siris gave 43.3% survival followed by leucaeana (30%). The lowest survival was in East Indian walnut (7%). This was under fencing compared to the earlier plantation which showed 66.6, 25.0 and 4.3% survival respectively.The same was with growth which showed 130, 278 and 340% higher values, respectively, under fenced condition for height of the species, Similar increase was observed in collar diameter due to fencing.

At site III, black siris, East Indian walnut and sissoo were planted under fencing. Maximum survival was in black siris (56%) followed by those in East Indian walnut (46%) and sissoo (42%). Compared to the previous findings survival improved in sissoo by 11% due to fencing. The growth in height of these species was 127, 186 and 374 % higher under fencing respectively. The collar diameter was 110 and 241% higher in East Indian walnut and sissoo due to fencing.

Thus, full protection assured higher rate of survival and growth in leucaena and sissoo. East Indian walnut performed better on site II than on site III. It appears to be due to the edaphic preference since there was no competition at the ground level.

b(iv) To Analyse and monitor the species performance in relation to existing micro-environments

Growth of Israeli babul on mounds and at the basins was compared at the end of 12 years of plantation. Growth on the mounds was better than

at the basin in terms of height, collar diameter and dbh growth. The difference was 1.70 m in height, 2.7 cm in collar diameter and 1.5 cm in dbh. This was mainly due to high saline sodic soil at the basin which interfered with the early tree growth. While soil pH was more than 9.5 at the basin, it was less than 8.5 on the mounds. So was the situation of electrical conductivity. The production of grasses on the top, slope and base indicated that production increased by 3.5 times between top and base. This was precisely because of low moisture retention in soil of the top compared to that of the base.

b(v) To test the biological and economic feasibility of the adapted silvi-pastoral models, and their carrying capacity under on-farm conditions

The surface vegetation developed through the introduction of grasses and *Stylo* showed a progressive increase over the years. By the close of the year the overall mean annual production was more on the slope (2.36 t/ha dry). On the top it was 2.2 t/ha. In the control plots it was about 2 t/ha. Amongst trees leucaena attained maximum height followed by mesquite. The minimum was in the case of *dhao*. The trees in treatment I showed higher growth compared to that in treatment II. The effect of the topographic elements on tree growth was not appreciable and did not show any definite trend. The natural vegetation regeneration showed maximum population density of 861 /ha at the base followed by those at slope and top. Maximum proportion of these was flame of forest and *ardanda*. Since the surface vegetation was still poor, grazing and carrying capacity studies will be carried out during 1994-95. The economic analysis will also be done on tree production to be observed this year.

3. TRANSFER OF TECHNOLOGY

The technologies have been transferred for complete application through the following mechanisms:

1. The results obtained are communicated every year to more than 500 agencies in the country giving the latest information.
2. National workshops organized on this specific subject have brought out recommendations for implementation (3 workshops were held in last II years and 1 is due in 1994).

3. The Institute-run training programmes also give a larger thrust to this system and the trained personnel have in turn taken up these activities in their respective areas. During the project period 12 Diploma Course Programmes of 9 months duration, 13 NARP trainings of 1 month duration, 20 Refresher courses, 2 Microplanning and Planning workshops were held.

4. Tested results were published in national and international research journals for wider dissemination.

5. With the help of Madhya Pradesh and Uttar Pradesh Governments large areas of the degraded forests have been put under silvipasture with technical assistance of the Institute.

6. The IGFRI has successfully demonstrated its technology on large degraded land areas allotted to the Society for Development Alternatives. The Society with Institute's technical help and guidance has further revegetated over 200 ha in Madhya Pradesh and 1,500 ha in Uttar Pradesh.

7. This technology is further being put to demonstration by the Institute on more than 500 ha of degraded forest and community wastelands in Uttar Pradesh and Madhya Pradesh with the help of National Afforestation and Ecodevelopment Board, New Delhi.

8. Under the National Watershed Project the technology is being demonstrated on a large area for the benefit of soil conservation and production of forage and firewood.

9. The Government of India-assisted Project on Forage Grass Seed Production at this Institute has been producing seed annually for wasteland development activity. The realization has been due to the success of this project.

10. The implementation of this technology is being assured in the country through Wasteland Development Project assisted by several agencies. The technology input is being provided.

11. This centre has given field demonstration on the introduction of legumes and trees in pastures along with the choice of species.

4. SOCIAL COSTS AND BENEFITS

Direct benefits

The programme on silvipasture funded by IDRC commenced in 1982. During the last 12 years trials were conducted on silvipasture development system dealing with improvement and rehabilitation of undulated uplands, gullies, ravines, degraded forest lands, wind eroded areas etc. To study the effects of the large investment made on the development of this technology to the ultimate beneficiaries of the programme, viz. the people living in the hinterland of the study area, an attempt was made to estimate benefits in terms of Internal Rate of Return (IRR), to a farmer. This analysis establishes the attractiveness or otherwise of the investment to the farmers and to the society at large. It projects the effect in income of a particular investment and estimates the return on the capital engaged. The analysis is projected over the useful life of the programme, viz. from the period beginning with the planting of trees in the farm, till they are cut for their ultimate use as timber.

For the purpose of the analysis, expenditure incurred by the farmer on items such as survey, soil water conservation work (swc), cattle proof trench (cpt), pit digging, watch and ward, etc. has been considered as his investment on land. Cost of land is not included since the project did not contemplate any change in ownership of land, but rather a change only in its use. If the shift from technology-1 or crop-1 is without changing the land ownership, the cost of land is its contribution to the value of production under technology-1 or crop-1 that the farmers must forego to use the land for technology-2 or crop-2. In the present case, the land was not in use before the silvipasture trial was made on it, and therefore its value before the programme is taken as nil for the social cost analysis. Cost of labour was computed on the basis of two alternatives, viz. (i) Institutional Management, as equivalent to the amount paid by IGFRI to their watch and ward staff, and (ii) Farmer Management, as only half the cost on watch and ward paid by IGFRI as the cost to the farmer. (The cost of the family labour is the benefit the family must forego to participate in the project or what the family would earn in its most remunerative alternatives.)

Similarly, the benefits included the yield received every year from the land as forage, grass seed, tree biomass etc. valued at market prices. The quantities of different yields considered as received during the period of the project, i.e. from year 1 to 12 under the programme are shown at Appendix V (i-ix).

The principal elements considered under costs and benefits each year are outlined at Appendix VI.

The analysis pertained to Israeli babul associated systems spread over 3 sites, viz. (i) undulated terrain with soil pH 6.38 to 7.69, (ii) eroded plains with soil pH 6.38-7.28, and (iii) ravine calcareous eroded plain with soil pH 8.12-9.82.The IRR for different alternative trials and different land terrains are given below. A brief note on IRR calculations is given at Appendix VII.

(IRR%)

Tree* spacings	Site I		Site II		Site III	
	A	B	A	B	A	B
4 m x 3 m	10	24	14	23	22	26
4 m x 4 m	5	24	9	22	18	23
4 m x 6 m	3	17	7	23	4	17

Site I : undulated terrain with soil pH 6.89-7.69

Site II : eroded plain with soil pH 6.38 -7.28

Site III : Ravine calcareous with soil pH 8.12 to 9.82

A : Institutional management cost as equivalent to the amount paid by IGFRI to their watch and ward.

B : Farmer management cost of family labour as equivalent to half the amount paid by IGFRI to their watch and ward

*Species grown in the sites

Species	Sites		
	I	II	III
Israeli babul	√	√	√
Black siris	√	√	√
Sissoo	-	√	√
Dicrostachys cinerea	-	-	√
Leucaena	√	√	-
Anjun	√	-	-
East Indian walnut	√	√	√

√ : Grown

- : Not grown

The IRR worked out to be higher in the case of farmer management, since the expenditure on labour input was lower in this case than in that of the Institutional trials. All the 3 locations under farmer management proved to be more or less equally beneficial. The IRR values were highest in 4 m x 3 m spacings. The technology as at per site III gives returns only towards the end of the project. The technology at sites I and II start giving returns from the very first year with higher lumpsum returns towards the end of the project. The small and medium size farmers might prefer the technology as at per sites I and II, and large well-to-do farmers might prefer as at per site III.

The higher rates of IRR indicate that farmers could successfully be induced to participate and take advantage. Intensive education is, however, necessary.

Net present value of net benefits

Net benefits are the differences between the benefits received in the form of yield from different species on the farm and the cost incurred to obtain the yields. The net present value of net benefits (NPVNB) is the present worth of net benefits of the project discounted at the opportunity cost* of capital.

$$NPVNB = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+i)^t}$$

Where Bt = benefits in year t
Ct = costs in year t
i = opportunity cost of captial

The above analysis is tentative and is based on the information provided by the IGFRI scientists during the period of visit of the consultants. A further probe into the items included under the inputs (items of expenditures / items of income) of the silvipasture farming system as well as the quantities of different yields (forage, grass, timber etc.) per hectare considered into the calculations is, however, necessary.

** The opportunity cost of capital is the return on the marginal investment which could be made over all the available capital fully invested in the most remunerative alternative manner.*

. The NPVNB of the investments made on 1 hectare of land for silvipasture development have been estimated for the duration of the project period of 12 years. These values in respect of sites I, II and III at an opportunity cost of capital of 15% are given below.

(Rs / hectare)

Tree spacing (m)	Net present value of net benefits (NPVNB)		
	Site I	Site II	Site III
4 x 3	4,865	6,303	14,330
4 x 4	4,112	4,679	7,875
4 x 6	3,543	4,517	1,595
Average	4,173	5,166	7,933

The average NPVNB of the expenditure by the farmers during the period of 12 years, at the opportunity cost of capital of 15% worked out to Rs 4,173, Rs 5,166 and Rs 7,933 for sites I, II and III respectively. On the average, for all the plots put together, the NPVNB worked out to Rs 5,757 or an appreciation of Rs 472 per year.

For the project on silvipasture, the IDRC funded an amount of Rs 6.055 million, of which Rs 2.065 million was allotted in the first phase and Rs 3.990 million in the second phase. ICAR made a matching grant of Rs 2.107 million in both the phases put together. Thus, a total amount of Rs 8.161 million was spent on this project for the development of technology on silvipasture for the benefit of farmers in Bundelkhand region in particular and to similar terrains in other areas of the country.

NPVNB analysis indicated the net benefit appreciation per hectare per year to be Rs 472. Thus it may be said that the total cost of technology development (IDRC support plus ICAR matching grant) would be returned to the community if the technology so developed is successfully applied on a land of about 17,000 hectares. Any participation higher than that would give returns higher than the investment at 15% opportunity cost of capital.

Bundelkhand region comprises 11 districts, viz. Banda, Jalaun, Hamirpur, Jhansi and Lalitpur in Uttar Pradesh, and Datia, Tikamgarh,

Chatarpur, Panna, Damoh and Sagar in Madhya Pradesh.This region has an area of about 3.4 million ha under forest, wasteland, fallows etc. which can benefit from the technology developed under the IDRC -supported silvipasture project. As indicated above the total cost of technology development incurred so far under the project can be expected to be fully recovered if the technology is adopted even in 0.5% of the total area under forest, fallows, wastelands etc. in this region.

This appears to be a feasible task in view of the need for developing the degraded land in this region and the infrastructure available with the concerned State Departments like Forest, Agriculture (soil conservation), Horticulture and Animal Husbandry. Thus, the investment made in the technology development under this project seems to be fully justified and promises adequate returns even with a little extension effort in promoting the usages of the technology generation.

Indirect benefits

In an economic appraisal of the project such as the present one, particularly with the components involving research in technology innovations, investments need to be judged not merely on the basis of commercial and financial viability but rather on the extent to which they serve the developmental aims of the country. In case of India these aims, inter alia, included reduction in regional imbalances, improved living conditions, maximization of the employment, maximization of per caput income etc. Some of the benefits likely to be accrued from this project are given below.

Regional development

The present work has shown a new technology dimension to many organizations dealing with improvement and rehabilitation of wastelands. The technology if utilized and implemented on areas under different types of degraded lands, can solve the problem of wasteland deterioration and land degradation. The land productivity improvement could take care of the increasing load of grazing animals on forage and people for fuel wood.

Land productivity

By adopting this technology it would be possible to raise land productivity by more than 8-10 times (forage, firewood and small timber) and the quality or nutritive value of output by 7 times.

At present, there is a wide gap in the demand and supply of forage and fuel availabilities in the country. This gap in demand and supply is expected to increase further with the increasing human and animal population. Wastelands and degraded forests, if put to this use, could help in bridging the gap to a very large extent.

The expected production of degraded lands, if brought under silvipastoral technology on say about 10 million ha area, is as under:

Products	Before the Project		Expected after the Project	
	Productivity (t/ha/year)	Production (mt/year)	Productivity (t/ha/year)	Production (mt/year)
Forage	0.5-1.0	5-10	4.0-5.5	40-55
Top feeds	-	-	1.6-2.5	16-25
Fire woods	-	-	2.0-3.0	20-30

The increase in nutritive value of forage by 6-7 times can further help in improving productivity of the livestock. Thus, the production of forage, firewood and small timber *in situ* will help prevent large-scale animal migration and forest destruction. Besides, it would also help in conservation of soil, water, nutrients and biodiversity.

Employment generation

The system promises sustainable level of employment to rural people in the activities of animal breeding, collection, processing and manufacturing value-added products from trees and grasses; and collection and trading of quality seed and other materials.

Some studies estimated that the establishment and management of silvipastures can generate in an average 10-year cycle 120 man days per hectare per year of employment. If the programme extends over 10 million ha of land, it can provide employment to about 4 million people annually. Other ancillary activities like processing of timber, furniture making, etc. provide employment to another 1 million people.

Environmental gains

The present situation of accelerating land degradation, viz. soil loss, nutrient loss and species loss, could be reversed by this process. It has been estimated that soil loss which is 17.78 t/ha a year under bare soil can be reduced to 1.26 t/ha a year under this system. Thus on 10 million ha it could save 165.2 mt top soil annually. Similarly 12.92 mt of soluble salts could be protected annually through this technology. By checking this colossal loss the land productivity could be restored. The improved infiltration rates will further enrich the underground streams to improve the irrigation and drinking water resources. The adoption of this technology on degraded lands has led to a rise in the number of species of grasses, legumes, trees and also animals. Thus, this system promises healthy environment and rich biodiversity which is so much essential for sustainable land productivity and human welfare.

5.DATA ANALYSIS

The data available on silvipasture programme was utilized for working out the averages of variables like yields and other tree parameters. Growth models were also developed, relating yield to tree characteristics with the use of regression techniques. However, while RBD split-plot techniques were used for the experiments in the fields on on-farm/on-station trials, no serious statistical analysis was attempted subsequently. They were therfore advised to attempt analysis of variances with the available data to work out the effects of trees on grasses, legumes etc.

Establishment of seasonal patterns in grass fodder

Silvipasture system supplements grass fodder shortage during the lean periods of availability of surface vegetation with fodder from trees obtained by lopping. In this connection optimum conservation plans on grass and tree fodders could be worked out if the seasonal patterns are established on the availability of fodder under these two categories. This can be done by modelling the data on grass and tree yields by a time series analysis. On the basis of the established seasonal patterns, an efficient lopping management system for optimal use of fodder in a sustainable manner could be designed.

A study of the available information at the IGFRI on grass and tree yields showed clear patterns. The methodology to be adopted for this purpose was explained to the statistician attached (part time) to the silvipasture studies with an example using the available data.

APPENDIX I

VISIT SCHEDULE OF REVIEW TEAM

Date	Time	Place
1.9.94	8.30-2.00	Discussions with Director, IGFRI and staff of Silvipasture Project and general appraisal.
	3.00-5.30	Discussions with the Director, NRCAF and Project Staff of Agroforestry Project
2.9.94	8.30 -2.00	Field visit - Silvipasture Project to sites II, III, IV & Operational Extension areas.
	3.00-7.00	Discussion with Silvipasture Project staff on the data collection and their analysis.
3.9.94	8.30-11.00	Field visit - Agroforestry Project (NRCAF)
	11.30-2.00	Discussion with Silvipasture Project staff on the work done by different scientists engaged on the Project since the beginning to date.
	3.00-6.00	Discussion with Silvipasture Project staff on social cost-benefit analyses
4.9.94	9.00-12.45	Discussion with Project staff of Silvipasture Project
	3.00-7.30	Field visit-Silvipasture Project
5.9.94	8.30-2.00	Visit to on-farm experiments of Agroforestry
	3.00-5.30	Discussions with Agroforestry Scientists on data collection and analysis.
	5.30-8.00	Discussion with Silvipasture Project staff and data analysis
6.9.94	8.30-12.0	Visit to Silvipasture Project, Site I Discussions with the officers of the forest department and visits to thier sites
	12.0-2.0	Agroforestry Project discussion
	3.00-6.00	Silvipasture Project discussion
7.9.94	8.30-1.00	Silvipasture Extension field visit Discussions with the officers of Development Alternatives Visit to check dams and fields developed by Development Alternatives
	2.30-5.30	Discussion with Silvipasture Project staff
8.9.94	8.30-2.00	Programme Discussion and future outlook
	3.30-5.00	Concluding session with Director, IGRI and NRCAF
	5.15	Departure

APPENDIX II

LIST OF ON-STATION AND ON-FARM TRIALS UNDER IDRC AGROFORESTRY PROJECT

	Name of the trial	Year of commencement
	ON-STATION (NRCAF)	
1.	MPTs for Boundary Plantation (rainfed)	1989-90
2.	MPTs for Boundary Plantation (partially irrigated)	1989-90
3.	Studies of alley cropping systems	1990-91
4.	Energy plantation (rainfed)	1992-93
5.	Energy plantation (partially irrrigated)	1992-93
6.	Agri-silvicultural studies with *Albizia* species under rainfed conditions	1993-94
7.	Agri-silvicultural studies with *Acacia* species under rainfed conditions	1993-94
8.	Intercropping studies on bamboo under rainfed condition	1993-94
9.	Agri-horticultural studies on citrus	1993- 94
10.	Evaluation of MPTs under wasteland	1993-94
11.	Agri-silvicultural studies with silver oak	1994-95

ON-FARM TRIALS (10 TRIALS)

Village	Farmer		Trial	Year
Karari	1.	Pd. Hariram Sharma	Agri-horticultural trial	1989-90
	2.	Shri Tijju	i)Agri-horticultural trial with guava, amla and pomegranate	1993-94
			ii) Ber based Agri-horticultural studies	1993-94
	3.	Shri Lallu	i) MPTs for boundary plantation (eucalyptus, leucaena)	1992-93
			ii) MPTs for boundary plantation (sissoo and *karonda)*	1991-92
	4.	Smt Kasturi	Agri-horti-silvicultural trial with guava	1994-95
			Agri-horti-silvicultural trial with citrus	1994-95
Bhatt-agaon	1	Shri Kuddus Ali	Agri-horticultural trial	1991-92
Simardha	1.	Shri Ramsahay	Agri-horticultural trial	1992-93
Ambabai	1.	Md.Omar Khan	Improvement of natural *zharberi* through *in situ* budding of improved variety	1993-94

APPENDIX III

NAMES OF MULTI PURPOSE TREES, FRUIT TREES GRAIN CROPS AND GRASSES

English name*	Botanical name
MPTs	
*Anjun**	*Hardwickia binata*
Ardanda	*Capparis zeylanica*
Babul acacia(*desi* babul)	*Acacia nilotica*
Black siris (*kala* siris)	*Albizia odoratissima*
Common sesban	*Sesbania sesban*
Dhao	*Anogeissus pendula*
East Indian Walnut (Siris *desi*)	*Albizia lebbeck*
Eucalyptus *(safeda)*	*Eucalyptus tereticornis*
Flame of the forest (palas, dhak)	*Butea monosperma*
Israeli babul	*Acacia tortilis*
Kassod tree	*Cassia siamea*
Khejari	*Prosopis cineraria*
Margosa(neem)	*Azadirachta indica*
Mesquite*(vilayati babul)*	*Prosopis juliflora*
Ram kanti	*Acacia cupressiformis*
Silver oak	*Gravellia robusta*
Sissoo*(shisham)*	*Dalbergia sissoo*
Thorny bamboo*(bans)*	*Bambusa arundinacea*
Yellow siris	*Albizia amara*
White popinae, Leucaena (subabul)	*Leucaena leucocephala*
White siris*(safed* siris)	*Albizia procera*
FRUIT TREES	
Amla*(aonla)*	*Emblica officinalis*
Guava *(amrud)*	*Psidium guajava*
Indian jujube (ber)	*Ziziphus mauritiana*
Lime *(nimbu)*	*Citrus aurantifolia*
Mandarin orange (Kinnow)	*Citrus reticulata*
Pomegranate *(anar)*	*Punica granatum*
Sweet orange *(mushambi)*	*Citrus sinensis*
GRAIN CROPS	
Blackgram	*Vigna mungo*
Gram/ chickpea	*Cicer arietinum*
Greengram	*Vigna radiata*
Groundnut	*Arachis hypogaea*
Sesame	*Sesamum indicum*
Soybean	*Glycine max*
Wheat	*Triticum aestivum*
GRASSES	
Bunch grass or buffel grass*(anjun)*	*Cenchrus ciliaris*
Guinea grass (*ginni* grass)	*Panicum maximum*
Spear grass *(shurval)*	*Heteropogon contortus*
Sehima grass *(sedwa)*	*Sehima nervosum*

* Names in italics(parentheses) are Hindi/common names.

APPENDIX IV

PARAMETERS OF TREES AND CROPS ON WHICH DATA WERE RECORDED

Item of information	Frequency of recording
Tree - based data	
1. Establishment/Survival (%)	Quarterly
2. Plant height	Quarterly in the first year and half yearly thereafter
3. Collar diameter	Half yearly
4. Canopy diameter	Half yearly
5. Diameter at breast height	Half yearly (not recorded for fruit trees)
6. Pruning/ pollarding of MPTSs	Half yearly
7. Crown diameter	Half yearly (recorded for each crop-season)
Crop - based data/Annual (Kharif/Rabi)	
1. Plant population/0.5m row length	
2. Plant height	
3. No. of tillers/0.5m row length in wheat only	
4. No. of effective tillers/0.5m row length in wheat only	
5. No. of pods/plant	
6. No. of leaves/plant	In sesame and groundnut only
7. No. of branches/plant	In sesame and groundnut only
8. Grain yield	
9. Straw yield	
10. Test weight	

APPENDIX V (i)

YIELD PER HECTARE OF LAND DURING THE PERIOD OF THE PROJECT

Site I (4m x 3m spacing of trees)
(Undulated terrain with soil pH 6.89-7.69)

Value per ton (Rs.)

Forage	:	Rs. 500/-	Branch	:	Rs 500/-
Timber	:	Rs. 700/-	Grass seed	:	Rs 15/- per kg
Tree biomass	:	Rs 500/-	Ls + Bh leaf	:	

Year (end of)	Yield during the period						Total value of yield
	Forage (t/ha)	Grass seed (kg/ha)	Ls + Bh (t/ha)	Timber (t/ha)	Branch (t/ha)	Leaf (t/ha)	(Rs)
1st	4.39	25.00	-	-	-	-	2,570.00
2nd	5.53	60.00	-	-	-	-	3,665.00
3rd	4.93	60.00	-	-	-	-	3,365.00
4th	4.04	50.00	-	-	-	-	2,770.00
5th	4.11	-	-	-	-	-	2,055.00
6th	4.76	-	-	-	-	-	2,380.00
7th	4.97	-	-	-	-	-	2,485.00
8th	4.71	-	1.97	-	-	-	3,340.00
9th	4.85	-	2.63	2.05	1.55	0.13	6,015.00
10th	3.95	-	1.94	-	-	-	2,945.00
11th	3.65	-	1.34	-	-	-	2,495.00
12th	4.25	-	1.21	8.28	7.22	0.55	12,411.00

APPENDIX V(ii)

YIELD PER HECTARE OF LAND DRUING THE PERIOD OF THE PROJECT

Site I (4m x 4m spacing)
(Undulated terrain with soil pH 6.89-7.69)

Year (end of)	Yield during the period						Total value of yield (Rs)
	Forage (t/ha)	Grass seed (kg/ha)	Ls+Bh (t/ha)	Timber (t/ha)	Branch (t/ha)	Leaf (t/ha)	
1st	4.39	25.00	-	-	-	-	2,570.00
2nd	5.53	60.00	-	-	-	-	3,665.00
3rd	4.93	60.00	-	-	-	-	3,365.00
4th	4.04	50.00	-	-	-	-	2,770.00
5th	4.11	-	-	-	-	-	2,055.00
6th	4.76	-	-	-	-	-	2,380.00
7th	4.97	-	-	-	-	-	2,485.00
8th	4.71	-	1.54	-	-	-	3,125.00
9th	4.85	-	1.57	1.54	1.16	0.10	4,918.00
10th	3. 95	-	1.04	-	-	-	2,495.00
11th	3. 65	-	1.02	-	-	-	2,335.00
12th	4 .25	-	0.91	6.20	5.40	0.41	9,825.00

APPENDIX V(iii)

YIELD PER HECTARE OF LAND DRUING THE PERIOD OF THE PROJECT

Site I (4m x 6m spacing)
(Undulated terrain with soil pH 6.89-7.69)

Year	Yield during the period						Total value
(end of)	Forage (t/ha)	Grass seed (kg/ha)	Ls+Bh (t/ha)	Timber (t/ha)	Branch (t/ha)	Leaf (t/ha)	of yield (Rs)
1st	4.39	25.00	-	-	-	-	2,570.00
2nd	5.53	60.00	-	-	-	-	3,665.00
3rd	4.93	60.00	-	-	-	-	3,365.00
4th	404	50.00	-	-	-	-	2,770.00
5th	4.11	-	-	-	-	-	2,055.00
6th	4.76	-	-	-	-	-	2,380.00
7th	4.97	-	-	-	-	-	2,485.00
8th	4.71	-	1.11	-	-	-	2,910.00
9th	4.85	-	1.01	1.03	0.78	0.06	4,071.00
10th	3.95	-	0.88	-	-	-	2,415.00
11th	3.65	-	0.74	-	-	-	2,195.00
12th	4.25	-	0.74	4.13	3.60	0.28	7,326.00

APPENDIX V(iv)

YIELD PER HECTARE OF LAND DURING THE PERIOD OF THE PROJECT

Site II (4m x 3m spacing)
Eroded plain with soil pH 6.38-7.28)

Year (end of)	Yield during the period						Total value of yield
	Forage (t/ha)	Grass seed (kg/ha)	Lopping (t/ha)	Timber (t/ha)	Branch (t/ha)	Leaf (t/ha)	(Rs)
1st	5.00	25.00	-	-	-	-	2,875.00
2nd	4.54	60.00	-	-	-	-	3,170.00
3rd	5.31	60.00	-	-	-	-	3,555.00
4th	4.87	50.00	-	-	-	-	3,185.00
5th	4.73	-	-	-	-	-	2,365.00
6th	5.09	-	-	-	-	-	2,545.00
7th	4.97	-	1.81	-	-	-	3,388.75
8th	5.07	-	1.30	2.58	2.06	0.17	6,107.00
9th	4.95	-	1.60	-	-	-	3,275.63
10th	3.94	-	1.35	-	-	-	2,644.63
11th	4.66	-	0.75	10.19	9.39	0.70	14,880.75

APPENDIX V (v)

YIELD PER HECTARE OF LAND DURING THE PERIOD OF THE PROJECT

Site II (4m x 4 m spacing)
(Eroded plain with soil pH 6.38-7.28)

Year (end of)	Yield during the period						Total value of yield
	Forage (t/ha)	Grass seed (kg/ha)	Lopping (t/ha)	Timber (t/ha)	Branch (t/ha)	Leaf (t/ha)	(Rs)
1st	-	-	-	-	-	-	-
2nd	5.00	25.00	-	-	-	-	2,875.00
3rd	4.54	60.00	-	-	-	-	3,170.00
4th	5.31	60.00	-	-	-	-	3,555.00
5th	4.87	50.00	-	-	-	-	3,165.00
6th	4.73	-	-	-	-	-	2,365.00
7th	5.09	-	-	-	-	-	2,545.00
8th	4.99	-	1.35	-	-	-	3,162.21
9th	5.07	-	0.97	1.17	0.82	0.07	4,267.72
10th	4.95	-	1.20	-	-	-	3,074.33
11th	3.94	-	1.03	-	-	-	2,482.72
12th	4.66	-	0.56	6.19	5.19	0.41	9,741.93

APPENDIX V (vi)

YIELD PER HECTARE OF LAND DURING THE PERIOD OF THE PROJECT

Site II (4m x 6m spacing)
(Eroded plain with soil pH 6.38-7.28)

Year (end of)	Yield during the period						Total value of yield (Rs)
	Forage (t/Na)	Grass seed (kg/ha)	Lopping (t/ha)	Timber (t/ha)	Branch (t/ha)	Leaf (t/ha)	
1st	5.00	25.00	-	-	-	-	2,875.00
2nd	4.54	60.00	-	-	-	-	3,170.00
3rd	5.31	60.00	-	-	-	-	3,555.00
4th	4.87	50.00	-	-	-	-	3,185.00
5th	4.73	-	-	-	-	-	2,365.00
6th	5.09	-	-	-	-	-	2,545.00
7th	4.97	-	0.90	-	-	-	2,936.00
8th	5.07	-	0.65	1.29	1.04	0.08	4,320.00
9th	4.95	-	0.80	-	-	-	2,874.00
10th	3.94	-	0.67	-	-	-	2,306.67
11th	4.66	-	0.37	5.09	4.69	0.35	8,599.02

APPENDIX V (vii)

YIELD PER HECTARE OF LAND DURING THE PERIOD OF THE PROJECT

Site III (4 m x 3 m spacing)
(Ravine calcareous with soil pH 8.12-9.82)

Year (end of)	Yield per hectare of land during the period				Total value of yield (Rs)
	Grass seed (kg/ha)	Timber (t/ha)	Branch (t/ha)	Leaf (t/ha)	
1st	-	-	-	-	-
2nd	-	-	-	-	-
3rd	-	-	-	-	-
4th	-	-	-	-	-
5th	-	-	-	-	-
6th	750.00	-	-	-	11,250.00
7th	750.00	-	-	-	11,250.00
8th	750.00	-	-	-	11,250.00
9th	525.00	2.58	2.06	2.23	12,371.00
10th	525.00	-	-	-	9,450.00
11th	525.00	10.19	9.39	10.09	21,628.00

APPENDIX V (viii)

YIELD PER HECTARE OF LAND DURING THE PERIOD OF THE PROJECT

Site III (4 m x 4 m spacing)
(Ravine calcareous with soil pH 8.12-9.82)

Year (end of)	Yield per hectare of land during the period				Total value of yield
	Grass seed (kg/ha)	Timber (t/ha)	Branch (t/ha)	Leaf (t/ha)	(Rs)
1st	-	-	-	-	-
2nd	-	-	-	-	-
3rd	-	-	-	-	-
4th	-	-	-	-	-
5th	-	-	-	-	-
6th	750.00	-	-	-	11,250.00
7th	750.00	-	-	-	11,250.00
8th	750.00	-	-	-	11,250.00
9th	525.00	2.58	2.06	0.17	12,371.00
10th	525.00	-	-	-	9,450.00
11th	525.00	10.19	9.39	0.70	21,628.00

APPENDIX V (ix)

YIELD PER HECTARE OF LAND DURING THE PERIOD OF THE PROJECT

Site III (4 m x 6 m spacing)
(Ravine calcareous with soil pH 8.12-9.82)

Year (end of)	Yield per hectare of land during the period				Total value of yield (Rs)
	Tree seed (kg/ha)	Timber (t/ha)	Branch (t/ha)	Leaf (t/Na)	
1st	-				-
2nd	-				-
3rd	-				-
4th	-				-
5th	-				-
6th	375.00				5,625.00
7th	375.00				5.625.00
8th	375.00		-	-	5.625.00
9th	262.00	1.29	1.04	0.08	6,179.00
10th	262.00	-	-	-	4,716.00
11th	262.00	5.09	4.69	0.35	10,799.00

APPENDIX VI

ITEMS CONSIDERED FOR COST - BENEFIT ANALYSIS OF THE SILVIPASTURE PROGRAMME

	!st year	2nd year,	3rd year 12th year
Costs	Survey Soil water conservation works Cattle-proof trench marking Pit digging Watch and ward Fertilizer Tree seedling planting Watch and ward	Gap filling Fertilizer Watch and ward	
Benefits			
		Forage (all years)	
		Grass seed (1st four years) collection	
		Lopping tree biomass (from 7th year)	
		Timber Leaf Branch	9th and 12th year
Valuation			
	Forage : Rs 500/- per tonne		
	Grass seed : Rs 15/- per kg		
	Timber : Rs 700/- per tonne		
	Leaf and branch : Rs 500/- per tonne		

APPENDIX VII

A BRIEF NOTE ON INTERNAL RATE OF RETURN (IRR)

IRR = The discount rate such that (Present worth of benefits) = (Present worth of costs)

In mathematical formulation,

IRR is the discount rate i such that

$$\sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} = 0$$

where B_t = benefit in each year

C_t = cost in each year

$t = 1, 2 \ldots\ldots n$ (number of years)

i = interest rate

IRR represents the return over the life of the Project (in the present case, from the year the trees are planted till the end of their life when they were cut for the use of timber) on the resources engaged in the Project. The cash flow is discounted to determine its present worth. By trial and error one discount rate is found which is too low and which leaves a positive present worth and another discount rate is found which is too high and which leaves a negative present worth of the cash flow stream. This brackets the true IRR which may then be estimated by interpolation .

The interpolation rule is

$$\text{IRR} = \text{Lower discount rate} + \text{Difference between the 2 discount rates} \left[\frac{\text{Present worth of the cash flow at the lower discount rate}}{\text{Absolute difference between the present worth of the cash flow streams at the two discount rates}} \right]$$

APPENDIX VIII

SCIENTISTS MET AT NRCAF/IGFRI AND OTHER ORGANIZATIONS

NRCAF	
Dr. R Deb Roy	Director
Dr. P. Rai	Senior Scientist
IGFRI	
Dr. Punjab Singh	Former Director, IGFRI and currently Joint Director IARI
Dr. A. Rekib	Director , IGFRI (on the date of visit)
Dr. R. P . Singh	Director, IGFRI (on the date of departure of consultants)
Dr. P.S. Pathak	Principal Scientist
Dr. V. S. Upadhyay	Animal Scientist
Mr. M.M. Ray	Scientist
Mr T. A. Khan	Statistician
Dr. Bhat	Plant Pathologist
Dr. L.P.Misra	Scientist
Dr. Parihar	Scientist
Mr. S.K. Gupta	
Development Alternatives [Jhansi]	
Mr. Sahni	
Officers of the Forest Department, Jhansi	
Indian Agricultural Statisties Research Institute (New Delhi)	
Dr. Srinath	Scientist Statistician