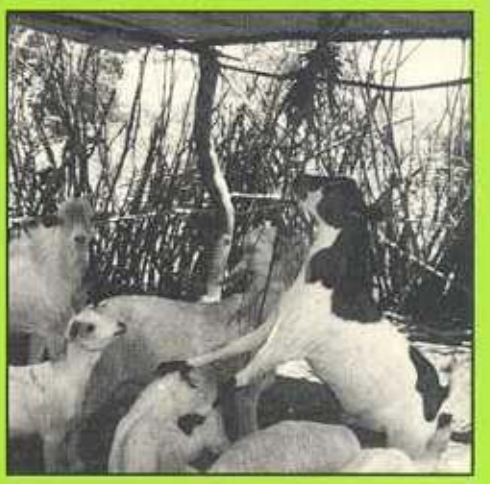
Economic analysis of agroforestry technologies

An annotated bibliography



Compiled by Rob A. Swinkels and Sara J. Scherr

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The International Council for Research in Agroforestry (ICRAF) is an autonomous, non-profit organization with a mandate to initiate and support research on agroforestry. It is governed by an international Board of Trustees with equal representation from developed and developing countries.

Established in 1978, ICRAF has its headquarters in Nairobi, Kenya. Financial support is provided by bilateral, multilateral and private donors. In 1991, these included the World Bank (International Bank for Reconstruction and Development), the African Development Bank, the International Fund for Agricultural Research (IFAD), the International Development Research Centre (IDRC), the Swedish Agency for Research Cooperation with Developing Countries (SAREC), the Ford Foundation, the Rockefeller Foundation, and the Governments of Australia, Canada, Finland, France, the Federal Republic of Germany, Japan, The Netherlands, Norway, Sweden, Switzerland, the United Kingdom (UK), and the United States of America (USA).

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Cover photos (clockwise from left): A farmer harvests bananas from an agroforestry plot in Kenya's Nyanza Province; maize, cassava, leucaena papaya and mango are planted on the same plot. Goats kept under zero grazing feed on fresh leucaena leaves on a farm in Kakuyuni, Kenya; the livestock enclosure is made from branches of local trees. A farm worker harvests pigeonpea at the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) in Patancheru, India.

FOREWORD

The need for 'hard' facts on the economics of agroforestry has been recognized for some time as a priority area by ICRAF and others. Such information is necessary to enable decision makers at all levels to allocate their resources efficiently. It not only helps answer questions concerning what resources should be allocated to agroforestry rather than to other potential activities, but it also assists in deciding how different resources should be combined for a particular agroforestry technology.

ICRAF is involved in generating information on the economics of agroforestry in three different ways. The first is through collaborative research programmes in four major agro-ecological zones of Africa. In each of these programmes, biophysical and socio-economic data are being collected on technologies developed on-station and on-farm. It is expected that substantial information will become available through these programmes over the next decade.

The council also supports other projects and organizations through the development of tools and methods for data collection and analysis. Several working papers have been prepared over the years and recently an annotated bibliography was published on technology monitoring and evaluation in agroforestry.

Finally, ICRAF has created and updated an inventory of the literature on economic aspects of agroforestry. The first annotated bibliography on this subject was produced in ICRAF's Working Paper series in 1983 and an updated version was published in 1985. Both versions were based on literature received from a network of economists dealing with agroforestry. In the past five years, many more publications have surfaced and the present bibliography attempts to bring the old and new information together. In the process, some additional indexes have been developed to classify publications and some of the previously listed publications have been removed since they have been superseded by newer and better material.

We hope that this new bibliography will help readers responsible for making decisions on the role of agroforestry within the whole spectrum of different land-use systems.

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An important source of material for this survey has been provided by researchers around the world who sent in documents in response to our request. We would like to thank all these colleagues. Without their contributions this bibliography would not have been complete. Their encouraging replies also stimulated our work.

We are grateful to Stef Mol for his initial work setting up the bibliography database and making contacts with potential contributors. He is also responsible for a number of bibliographic annotations.

We are also indebted to ICRAF economists Dirk Hoekstra and Marcelino Avila for their help in developing the right descriptors of the economic studies and for other valuable comments on initial drafts. Mr Hoekstra also put us in touch with numerous economists working in agroforestry. The two earlier ICRAF bibliographies that he produced provided a solid starting point for the present work.

The continuous support from ICRAF librarians, Stephen Okemo and Alfred Mureithi, is gratefully acknowledged. Without their good-humoured assistance our work would have been much less pleasant.

The assistance from ICRAF's information officers has also been crucial. We are especially grateful to Hilda Munyua, but also to Lucille Teemba, Bondole Bofete wa Mbula and Gilles de Chatelperron. ICRAF computer programmer, Stephen Mburu, deserves our gratitude for his help with the use of CDS/ISIS, the bibliographical database program.

Sidney Westley provided editorial assistance and the cover pictures were provided by Anthony Njenga. We have also benefited from Eva Müller's experience with the annotated bibliography on monitoring and evaluation in agroforestry projects, published by ICRAF in 1989.

Finally, we would like to mention the generous contributions of the Netherlands Government and the Rockefeller Foundation, which have made this bibliography possible.

Rob Swinkels
Sara Scherr

CONTENTS

Introduction

1 INTRODUCTION TO THE BIBLIOGRAPHY

Agroforestry as a land-use practice has gained considerable popularity in recent years due to its potential to address a wide range of household needs with a low level of external inputs and on a sustainable basis. However, this excitement should be accompanied by a detailed analysis of the real costs and benefits involved in adoption of specific agroforestry technologies. There is a need for more and better economic studies of agroforestry.

This annotated bibliography has been prepared as a comprehensive overview of existing literature on the economic analysis of agroforestry technologies. It should give people who plan to collect and analyse economic data on agroforestry access to a range of approaches, methods and experiences on which to build their work. The material collected is also relevant for drawing conclusions about the economics of particular agroforestry technologies.

This is an updated and improved version of two earlier bibliographies on the economic analysis of agroforestry technologies published by ICRAF (Hoekstra and Van Gelder, 1983; 1985). Since the most recent version five years ago, many new documents have been produced and new methods have been developed for economic studies in agroforestry. These have justified this new review: more than half the documents included here have been published since 1985. The format has been changed to provide more key information on each document, whereas some of the earlier descriptors have been dropped. Among the new descriptors are: data source, type of economic analysis, analysis level, and ecozone. Agroforestry technologies are also described in more detail. The documents may now be identified more easily through indexes according to the specific interest of the user. Abstracts have also been expanded to give a more complete description of the content of each document.

2 INFORMATION GATHERING: SOURCES AND METHODS

Published documents containing economic analyses of agroforestry technologies were collected from ICRAF and other libraries. Unpublished studies and so-called grey literature dealing with agroforestry economics were obtained by writing to people known at ICRAF to be involved in such work. Requests for relevant documents were put in both English and French issues of ICRAF's quarterly magazine *Agroforestry Today*, as well as in the newsletter of the American Agricultural Economics Association.

In addition, requests for documents were sent to members of the Social Forestry Network of the Overseas Development Institute who were identified as having an interest in agroforestry and economics. Unfortunately, Francophone and Latin

American contacts were relatively few. In total 219 letters were sent out with requests for relevant documents. The project received 49 responses (22%), all showing keen interest in the work, and 27 of these (12%) sent in documents. India provided the largest number of contributors, but generally responses came from all parts of the world.

During 1988-89, in order to compile another ICRAF bibliography on technology monitoring and evaluation in agroforestry projects, 166 agroforestry projects from all over the world were contacted for information on how they evaluated the technologies they promoted. Material from the respondents who mentioned carrying out economic studies (Müller and Scherr, 1989) is also included in the present bibliography.

In total, 230 documents were selected. Table 1 presents the regional distribution of the studies included in the bibliography. Nearly all are in English; three are in French and six in Spanish.

Table 1. Distribution of documents according to geographical region (total: 230).

REGION	NO OF DOCUMENTS	%
Asia	72	31
Africa	63	27
Latin America	28	12
USA/Canada	11	5
Europe	3	1
Australia/New Zealand	19	8
Global	37	16

Note: some documents concern more than one region.

Asia and Africa together provided more than half of the documents, each contributing almost one third. Asia was the largest contributor with 72 documents.

3 ORGANIZATION OF THE BIBLIOGRAPHY

3.1 Organization of entries

The annotated bibliography is presented in alphabetical order according to the surname of the first author. (However, a document by Jickling (1989) was received at the last minute and had to be entered at the end of the bibliography.) Each entry starts with a number at the top. These begin with 1 for the first and continue to 230 for the last entry. An 'A' or a 'B' follows, indicating the quality of the document. The 'A' documents have been evaluated as more useful for other researchers interested in carrying out economic analyses of agroforestry technologies than the 'B' documents. The criteria used in making these assessments were the

completeness of the economic analysis and the amount of detail provided on the data-collection process and on the agroforestry technologies concerned.

This is followed by the name of the author(s), the year of publication, and the title in English, together with the title in French or Spanish if either is the original language. The next line provides the source, journal volume and number if applicable, publisher, and place and country of publication. Next follows the number of pages, and the code for language, continent and country or countries where the agroforestry technologies are located. This is followed by the accession number in the ICRAF library and finally by the abstract and the descriptors.

3.2 Index summary

Thirteen indexes are included at the end of the bibliography for author, language, geographic location and ten key descriptors. These are ecozone descriptor, type of analysis, analysis level, data source, agroforestry technology, tree/shrub species, tree/shrub product, tree/shrub service, crop/grass species, and livestock species.

Each entry in the indexes refers to the number found at the top of the complete entry in the bibliography, ranging from 001 to 230. An example of a bibliographic entry is provided in Section 6 of this introduction. The index for geographic location is based on the two-letter codes of countries and continents provided by the International Standard Organization (ISO), and given in each annotation. These codes are explained in the index. Each indexed descriptor is briefly explained in the following paragraphs.

3.2.1 Ecozone

Ecozone descriptors refer to altitude and rainfall, using the classification presented below. Temperate climates are indicated as a separate category.

Humid	annual rainfall > 1600mm
Sub-humid	annual rainfall between 800mm and 1600mm
Semi-arid	annual rainfall between 400mm and 800mm
Arid	annual rainfall < 400mm
Highlands	altitude > 1000 meter above sea level
Lowlands	altitude < 1000 meter above sea level
Temperate	temperate climates

If a study does not concern a specific ecozone, this field is left blank. Table 2 shows the ecozones in which the reviewed agroforestry technologies are located. Humid climates (represented in 68 documents or 29% of the total) and lowlands (25%) seem to have received most attention in economic analyses of agroforestry technologies.

Table 2. Distribution of documents according to ecozone descriptor (total: 230).

ECOZONE	NO OF DOCUMENTS	%
Humid	74	32
Sub-humid	27	12
Semi-arid	37	16
Arid	6	3
Lowlands	63	27
Highlands	23	10
Temperate	28	12
Not specified	69	30

Note: studies may concern more than one ecozone.

3.2.2 Type of analysis

The descriptors used for the type of analysis are *whole-farm budgeting, partial budgeting, cost-benefit analysis, linear programming, non-linear programming, production-function analysis, agroforestry sector analysis, regression analysis, economic concepts/methodology* and *computer program*. These are explained in more detail in Section 4 on types of economic analysis.

3.2.3 Analysis level

Economic analysis of agroforestry may be carried out from different points of view and at different levels. We have defined the following categories.

Research plot: In research-plot studies, economic inputs and outputs are documented from experimental plots, usually to provide indications of economically promising treatments.

Farm: Farm studies include those carried out from the farmer's perspective for household-managed farms or for specific farm plots.

Plantation: Plantation studies focus on the economics of agroforestry in plantations. These may be forest plantations (e.g., taungya systems or trees mixed in grazing land managed by a forest department) or large public-owned estates with tree crops.

Project: Project studies deal with the economics of agroforestry systems at the project level, generally rural development or agroforestry projects.

Community: Community studies are defined as those carried out from the point of view of rural communities or villages.

Region: Regional studies are those carried out to determine the economics of agroforestry in a particular geographical region of a country.

Country: These studies are from a national point of view and carried out to evaluate the economics of agroforestry for a single country or a group of countries.

Table 3. Distribution of studies according to level of analysis (total: 230).

ANALYSIS LEVEL	NO OF DOCUMENTS	%
Research plot	31	13
Farm	150	65
Plantation	26	11
Project	27	12
Community	25	11
Region	51	22
Country	16	7
Not specified	11	5

Note: studies may have more than one level of analysis.

Table 3 gives a breakdown of the studies covered in the bibliography according to the level of analysis. The most common level of analysis is the farm (150 documents or 65% of the total), which includes studies of agroforestry on individual farm plots as well as the economic role of agroforestry in the whole farm enterprise. Next in frequency are regional analyses (22%) and economic analyses at research plot level (13%).

3.2.4 Data source

The data in the economic analyses reviewed are classified as empirical (generated from a real situation), non-empirical (theoretical) or not specified (method of data collection not indicated). However, often a combination of various data sources is used. Where no information is provided in the annotation on data sources this indicates the study does not present any economic data, for example, in a paper discussing the theory of economic analysis. The subdivision is as follows:

Empirical

Case studies: Case-study data are drawn from a small number of farms, communities or plantations, studied in some depth to illustrate typical levels of economic returns. Data generated from on-farm research are included in this category.

Farm survey: Farm-survey data are collected by interviews or field measurements from a sample of farmers using the agroforestry technologies being studied. This category includes both informal surveys and those using a formal sampling frame.

Research plot: Research-plot data concern inputs and outputs collected from experimental plots, fully or partially managed by researchers.

Non-empirical

Estimates: Analyses based on estimates use values for economic coefficients or variables drawn from similar situations, local informants, or reasonable assumptions based on local knowledge.

Biological models: Data generated by biological models are the outcome of mathematical equations which simulate tree, crop, grass or livestock growth and yield.

Unspecified

Unspecified: In this case the method of data collection is not indicated. This category includes data quoted from other documented research findings, the *actual* source of which is not specified.

Table 4. Distribution of studies according to source of data (total: 230).

DATA SOURCE	NO OF DOCUMENTS	%
Case studies	45	20
Farm survey	76	33
Research plot	64	28
Estimates	100	43
Biological models	15	7
Unspecified	53	23
No data	39	17

Note: documents often have more than one data source.

As shown in Table 4, in 76 documents, or a third of the total, at least some of the data are from a farm survey. Economic studies carried out in 'real' farm environments are still rare; only 20% uses data collected through on-farm case studies and many documents depend at least partly on results from on-station research plots (28%) or estimates (43%) (see also reviews by Jickling (1989) and Swinkels (1990)). However, ICRAF received a number of replies from agroforestry projects mentioning that economic studies are on-going and that results are expected soon. Within ICRAF's Agroforestry Research Networks for Africa (AFRENAs), on-farm economic studies of agroforestry technologies have been initiated and will be expanded in future.

3.2.5 *Agroforestry technology*

An agroforestry technology may be defined as a distinctive arrangement of woody and non-woody components in space and time, designed to perform specific functions through appropriate management inputs. For convenience, specific technologies are often named according to spatial or temporal arrangements of the tree component and are categorized as such.

Specific methods for economic analysis depend partly on the type of technology to be evaluated. For example, a cost-benefit analysis to calculate the profitability of hedgerow intercropping will use a different approach than a similar analysis for trees in pasture. Therefore, for each document that includes a particular type of economic evaluation, the agroforestry technology concerned is indicated. General definitions of agroforestry technologies given here are based in part on Müller and Scherr (1989), and on ICRAF in-house terminology. Some documents do not mention a particular technology but, for example, elaborate on general methodological issues. In such cases the field for agroforestry technology is left blank. Table 5 lists the major agroforestry technologies covered in the documents.

Mixed planting

Trees in homegarden: Homegardens are multistoreyed systems with multi-purpose and fruit trees planted at high densities on small pieces of land and managed to provide a wide range of products. All kinds of crops are grown underneath.

Trees mixed in annual cropland: Trees, usually dispersed at low densities, are combined with annual crops. Trees may be planted, may be established by encouraging natural regeneration, or may simply be left standing when the field is cleared. To reduce shading of crops, trees in cropland are generally pruned. Leguminous trees may be planted specifically for soil-fertility enhancement through the production of mulch. Trees may also be grown primarily to produce timber, poles, fruit, firewood or livestock fodder.

Trees mixed in perennial cropland: Perennial crops are intercropped with trees. Often, the trees are planted at a regular spacing specifically to provide shade for crops, as in the case of cocoa and coffee. Trees may also be grown to provide other products and services as are trees mixed in annual cropland.

Trees in pasture: Trees dispersed in pastures may provide fodder, timber or shade for livestock. The trees are either left standing when forest is cleared for pasture establishment, planted, or established through encouragement of natural regeneration.

Block planting

Woodlot: This is a group or block of trees grown mainly to provide construction wood or fuelwood. Crops may be grown adjacent to woodlots, but generally not within them. The trees may be pruned and occasionally the stands may be thinned.

Fodder bank: These are groups of trees grown for fodder and managed to favour leafy biomass production. Tree species used for this purpose are usually leguminous.

Strip/Line Planting

Hedgerow intercropping (alley cropping): Leguminous trees are grown in rows in cropland with regular spacing between the rows. The main purpose is to provide leafy biomass for mulch (green manure) or fodder. Fuelwood is occasionally harvested as a by-product. The trees are intensively managed by cutting back at frequent intervals.

Contour planting: Lines or strips of trees are grown along contour lines or terraces on sloping land in cropland. The main objective is to provide physical barriers for soil conservation. In addition, the trees may be managed for the production of fuelwood, fodder or mulch.

Boundary planting: Lines or strips of trees are planted along field or farm boundaries or on rice paddy bunds. The purpose is to provide timber, fuelwood, fruit or fodder. The planting configuration and location may be chosen to take advantage of unutilized space on farmland, to avoid direct competition with crops or to demarcate property boundaries. Management depends on the expected products. If the trees are grown adjacent to crops, they are generally side-pruned.

Live fence: Lines of trees or shrubs are planted on farm boundaries or on the border of home compounds, pastures, fields or animal enclosures. Their primary purpose is to control the movement of animals or people. Live fences (or living fences) may also provide fuelwood, fodder and food and may act as a windbreak or enrich the soil, depending on the species used (Westley, 1990).

Windbreak: Trees are planted in lines or strips in fields or pastures for wind protection. Occasionally they are harvested for timber or fuelwood.

Sequential/Rotational Planting

Taungya afforestation: Tree plantations are established by intercropping seedlings with annual food crops during the first few years to reduce establishment costs and to provide rural dwellers with cropland, at least temporarily.

Improved tree fallow: Trees are planted on fallow fields to maintain or improve soil fertility and to provide products that increase the economic value of the fallow. The trees are generally harvested when the land is replanted with crops. Most often, leguminous tree species are used.

Table 5. Distribution of studies according to agroforestry technology (total: 230).

AGROFORESTRY TECHNOLOGY	NO OF DOCUMENTS	%
Trees in homegarden	9	4
Trees mixed in annual cropland	57	25
Trees mixed in perennial cropland	21	9
Trees in pasture	44	19
Woodlot	54	23
Fodder bank	6	3
Hedgerow intercropping	.32	14
Contour planting	10	4
Boundary planting	11	5
Live fence	6	3
Windbreak	13	6
Taungya afforestation	32	14
Improved fallow	12	5
Not specified	46	20

Note: studies may cover more than one technology.

Table 5 indicates that the agroforestry technologies most frequently evaluated in the economic studies are trees mixed in annual cropland (57 documents or 25% of the total), woodlot (23%), trees in pasture (19%), hedgerow intercropping (14%) and taungya afforestation (14%). There are few studies of fodder banks or live fences (each 3%).

3.2.6 Tree/shrub species

If an agroforestry tree/shrub species is specified in a document it is given as a descriptor. Tree crops are included in this category. The documents cover a wide variety of trees/shrubs: a total of 147 different species. The most frequently mentioned are presented in Table 6.

Table 6. Most frequently mentioned trees and shrubs (total: 230).

TREE/SHRUB SPECIES	NO OF DOCUMENTS	%
Leucaena leucocephala	52	23
Eucalyptus spp.	35	15
Acacia spp. (excl. *Faidherbia albida*)	27	12
Pinus spp.	26	11
Cocos nucifera	14	6
Gmelina arborea	12	5
Prosopis spp.	12	5
Tectona grandis	12	5
Theobroma cacao	12	5
Azadirachta indica	8	3

Note: often studies mention more than one tree/shrub species.

Leucaena leucocephala is mentioned most often in the economic studies (52 documents or 23% of the total), followed by eucalyptus (15%), *Acacia* species (12%), and *Pinus* species (11%).

In this bibliography, *Acacia albida* appears as *Faidherbia albida.*

3.2.7 Tree/shrub product

In agroforestry, trees and shrubs may provide a number of products. These are specified in 171 documents and appear as a descriptor. The most common are: fuelwood (83 studies or 36% of the total), timber (35%), fodder (18%), poles (13%), fruit (13%) and mulch (10%).

3.2.8 Tree/shrub service

Trees and shrubs also provide a number of services. These are specified in 65 of the documents. The most common are: soil conservation (33 studies or 14% of the total), soil-fertility improvement (13%), shade (9%) and fencing (3%).

3.2.9 Crop/grass species

Crop or grass species are indicated in 105 documents and appear as a descriptor in the annotations. For crops, English names are used, whereas scientific names are used for grasses. The common crops are: maize (59 documents or 21% of the total), cassava (10%), rice (9%), beans (7%), sorghum (6%) and wheat (5%). Most common grasses are *Pennisetum purpureum* (2%) and *Stylosanthes* species (1%).

3.2.10 Livestock species

An animal component of the agroforestry technology is specified in 49 of the documents. Most common are: cattle (27 studies or 12% of the total), sheep (11%), goats (3%) and poultry (2%).

4 TYPES OF ECONOMIC ANALYSIS

The types of economic analysis described in the documents are divided into the following categories, which are not mutually exclusive. Definitions are partly based on Upton (1987).

Farm budgeting: Studies to quantify the effects of an agroforestry technology, but not accounting for the value of time. Inputs and outputs are quantified, covering one or several years or seasons, in order to assess the economic viability. Farm budgeting studies are sub-divided between *whole-farm budgeting* and *partial budgeting*.

Cost-benefit analysis: This involves assessing resource inputs, costs and benefits over the whole lifetime of a planned or existing agroforestry technology, considering it as a medium- or long-term investment. Discounting techniques are then used to be able to compare costs and benefits which occur in different time periods.

Optimization techniques: These aim at an optimal allocation of resources. They are subdivided between *linear programming* (including multi-objective programming), *non-linear programming* and *production-function analysis*

Agroforestry sector analysis: Studies evaluating economic incentives and other factors at farm, and regional or national level.

General concepts and methodology: These deal explicitly with theoretical or methodological issues of agroforestry economics. A sub-category here is *computer program*, which contains studies which develop a program for computer analysis of economic data in agroforestry.

Regression analysis: Studies to explore relationship between economic variables, generally using survey data.

Both farm budgeting studies and the cost-benefit analysis type of studies are divided into ex-ante, ex-post, and ex-ante and ex-post studies.

Ex-ante analyses help determine the feasibility of a possible future allocation of resources. These are carried out for planning purposes, on the basis of estimates of costs and returns. The aim is to estimate the probable effect of a new agroforestry practice on farm resource requirements, farm income, or the larger economy, or to test its expected economic viability.

Ex-post studies are used to evaluate a past allocation of resources. They are evaluations of existing agroforestry technologies based on actual inputs and outputs during the full production cycle, either on-station or on-farm.

Other studies are defined as *ex-ante and ex-post*. These are analyses partly based on input-output data collected during the initial stages of the agroforestry technology and partly on the projected future flow of costs and benefits.

4.1 Farm budgeting

In farm budgeting a microscopic view is provided of the costs and returns of a farm or farm enterprise in a particular season or year, or for a few years or seasons. The costs and returns are not discounted. Such analyses may be carried out to quantify the effect of an agroforestry intervention by comparing such costs and returns on the basis of gross margin (with no value attached to labour), net cash income, net cash plus non-cash income, or net income including the costs of capital. As in cost-benefit analysis, farm budgeting may include analysis of the use and productivity of resources such as land, cash and labour. In the studies covered in this bibliography, farm budgeting is nearly always conducted at farm or research-plot level. Farm-budgeting studies are divided here between whole-farm budgeting and partial budgeting, depending on at what level the budgets are prepared.

4.1.1 Whole-farm budgeting

Whole-farm budgets are assessments of the overall impact of an agroforestry technology on the whole system and include budgets for the complete farm. The feasibility of the technology is tested in terms of its resource requirements and how this affects other farm enterprises.

4.1.2 Partial budgeting

Partial budgets are used where it is assumed the agroforestry technology only effects a particular enterprise or sub-system, which can then be considered separately. Only those items likely to change, i.e. the extra costs and benefits due to the technology, are included in the partial budget.

4.2 Cost-benefit analysis

In cost-benefit analysis the life-time costs and benefits of an allocation of resources are compared in order to assess its economic efficiency. Costs and benefits do not occur at the same time: normally the cost comes before the benefit and this is especially so in agroforestry where trees only yield benefits after some time. Therefore, the analysis includes discounting to allow for this time difference. This entails using an interest rate to bring back (discount) all costs and benefits to the same year (usually year 1). Comparisons are then in terms of this discounted flow of costs and benefits, also called 'net present value' (NPV), i.e. discounted benefits minus discounted costs. The benefit/cost (B/C) ratio is also used - the outcome of dividing the discounted benefits by the discounted costs. Another measure is the

internal rate of return (IRR), which is the interest rate at which the net present value equals zero, or the benefit/cost rate is one.

Cost-benefit analysis can be done from different perspectives. This is specified in the bibliographical annotations in the descriptor for 'level of analysis' (section 3.2.3). In *financial analysis*, the study is done from the perspective of the entrepreneur (farmer), and inputs and outputs are valued at market prices. *Economic analysis* is done from the perspective of the society as a whole; market prices of inputs and outputs are corrected if these do not reflect their real values. This bibliography contains mostly financial analyses. The few cases of economic analysis are indicated as *cost-benefit analysis (economic)*.

In both farm-budgeting and cost-benefit analysis studies, the analysis does not lead in a systematic way to an 'optimal' or most profitable solution. It can be used to identify the most profitable of a set of alternative plans, but it does not guide the choice of alternatives for evaluation.

4.3 Optimization techniques

Optimization techniques are analyses used to identify optimum combinations of resources. This may involve linear programming (including its variation 'multi-objective programming'), non-linear programming or production function analysis.

4.3.1 Linear programming

Linear programming entails optimization under specific resource constraints and a particular objective function. It permits analysis of a wide range of alternative, non-marginal adjustments and involves a rigorous specification of constraints (resources available) and detailed input-output data. Activities are precisely defined. Production coefficients are specified in terms of inputs required per unit of a given activity. A variation of linear programming is multi-objective programming. This allows identification of more than one major objective function, which can then be used to generate alternatives, rather than just one 'optimal' solution. Use of linear programming is constrained by its requirements for stable returns to scale in the use of all inputs.

4.3.2 Non-linear programming

Studies based on non-linear programming use models that allow for non-linear relationships. These may include changing returns to scale in input use, other non-linear constraints or a non-linear objective function.

4.3.3 Production-function analysis

Production-function analysis looks in detail into the relationship between inputs and outputs. This relationship can be linear and non-linear. In this type of analysis, production functions are used to evaluate *marginal* changes in quantities or prices of inputs and outputs in the short to medium term in order to identify optimal points of operation. The relationships between inputs and outputs are often

depicted geographically. The development of production functions requires many observations of input-output relationships at different levels of inputs. Such information may be provided either through experimental data designed specifically to generate production response, or through the collection of survey data from farmers operating with different levels of inputs.

4.4 Agroforestry sector analysis

Agroforestry sector analyses evaluate the economic factors or the economic infrastructure affecting agroforestry production at the farm and regional or national level. They cover the economic context for household decision-making about agroforestry adoption or investment as well as economic factors influencing agroforestry production in general. Such economic factors include the relative prices of agroforestry and non-agroforestry products and access to production inputs such as land, labour and capital. Agroforestry sector analyses also include market studies that evaluate the structure and function of markets for agroforestry products and their effect on farmers' economic returns from agroforestry technologies. More general studies of tree-product demand and pricing (e.g. fuelwood-demand studies) are not included. Analysis of economic policy also falls under the umbrella of agroforestry sector analysis.

4.5 Regression analysis

Regression analysis is a technique used to explore correlation between variables. In this bibliography it is used to test relationships between economic variables or economic and non-economic variables, using data from surveys among agroforestry farmers.

4.6 Economic concepts and methodology

Studies described as economic concepts/methodology deal explicitly with general theoretical or methodological issues of agroforestry economics. Most often, these refer to one of the above areas of analysis, but they may not contain a specific analysis. A sub-category consists of computer programs.

Table 7 shows how many studies based on different types of analysis are included in the bibliography. Cost-benefit analysis was most common (54%), followed by farm budgeting (45%). In cost-benefit analysis, ex-ante analyses far outnumbered ex-post analyses. Only 13% of the entries involved optimization models. A large proportion (30%) focused on the economic concepts and methodology of economic analysis of agroforestry technologies, and 18% concerned agroforestry sector analysis. Documents using cost-benefit analysis with economic prices were few (3%). Only one partial-budgeting study used economic prices.

4.6.1 Computer programs

Several documents in the bibliography include computer programs for analysis of economic data in agroforestry. These are either complete new software packages such as MULBUD, programs written within general and commercially available software, or programs facilitating the transfer from one package to another.

MULBUD is a computer program for the economic analysis of multi-period and multi-enterprise farm budgets. It is now only available from the Development Studies Centre of the Australian National University, and cannot be ordered from ICRAF.

Table 7. Distribution of studies according to type of economic analysis (total number: 230).

TYPE OF ANALYSIS	NO OF DOCUMENTS		%	
Total farm budgeting	45		20	
Partial budgeting [a]		36		16
Whole-farm budgeting		9		4
Total cost-benefit analysis	124		54	
ex-ante		67		29
ex-post		29		13
ex-ante and ex-post		22		10
economic analysis		6		3
Total optimization model	31		13	
Linear programming		18		8
Non-linear programming		5		2
Production-function analysis		8		3
Agroforestry sector analysis	41		18	
Regression analysis	3		1	
Economic concepts/methodology	70		30	
Computer programs		9	4	

[a] One also used economic prices.
Note: many documents include more than one type of analysis.

5 ORDERING DOCUMENTS FROM ICRAF

All documents listed in the bibliography are available from ICRAF and can be consulted in the ICRAF library. Photocopies of documents are available to individuals and institutions from developed countries at a charge of US 0.20 per page. A maximum of 10 documents will be photocopied free of charge for nationals or institutions from developing countries. Books will not be photocopied for reasons of copyright. When requesting documents, the name of the author, the title and the ICRAF library accession number should be indicated.
Requests for photocopies of documents presented in this bibliography may be referred to:

INFODOC/ICRAF, P.O. Box 30677, Nairobi, Kenya.
Telephone: 254 (2) 521450, Telex: 22048, Telefax: 521001, Cable: ICRAF,
E-mail: 157:CGI236.

6 SAMPLE ENTRY

1. Master file number_____039
2. Quality and usefulness rating_____A
3. Author_____DAVIS, L.S.
4. Year of publication_____(1989)
5. English title_____ANALYSIS OF AGROFORESTRY SYSTEMS: A WORKBOOK OF SUPPLEMENTAL TEACHING MATERIAL
6. Title in original language (if not English)_____
7. Source, publisher, place of publication_____Morrilton, Arkansas, USA: Winrock International
8. Volume/issue number_____
9. Pagination_____pp. 203
10. Language of text (EN= English, FR= French, ES= Spanish)_____EN
11. Geographical location (see index for explanation of codes)_____XZ/XP/SL/CH
12. ICRAF accession number_____12469

13. Annotation_____This workbook makes an important contribution to the development of economic analysis of agroforestry systems. It has three purposes. First, it presents a conceptual framework in which to quantify, analyse, and evaluate the dynamic nature of agroforestry systems. Second, it makes linear programming a practical tool for analysing agroforestry systems; it provides a

software program on diskette to move data from a Lotus 1-2-3 spreadsheet to LINDO, a widely used computer program for linear programming. Third, it illustrates the use of the conceptual framework and analytical techniques in three case examples. As an introductory example, a simple model is presented of a hypothetical family farm growing beans or beans intercropped with trees. This is expanded by adding different land types, management prescriptions, environmental impacts, crop storage, nutritional requirements, labour 'export and import', price expectations, modelling of supply and demand curves, and finally by introducing the banking and government sector. Absolute, flow and ratio constraints are used. Some constraints are linked. A number of options for a 'strategy for analysis' are presented. A separate chapter provides information on computers, software and file management for this analysis. Lastly, two examples are provided using empirical data: case studies of Sri Lanka forest-garden development and a south China village development project. The book is in draft form for testing by students and working professionals in training workshops. A final version is expected in 1992.

14. ECOZONE	humid highlands, sub-humid lowlands
15. TYPE OF ANALYSIS	optimization model, computer program
16. ANALYSIS LEVEL	farm, project, community
17. TECHNOLOGY	woodlot, taungya afforestation, trees in homegarden, trees mixed in annual cropland
18. TREE/SHRUB SPECIES	*Persea americana, Eucalyptus* spp, *Gliricidia* spp, *Grevillea* spp, *Psidium guajava, Mangifera indica, Carica papaya, Pinus* spp, *Bambusa* spp, *Cunninghamia lanceolata*
19. TREE/SHRUB PRODUCT	fruit, timber
20. TREE/SHRUB SERVICE	soil fertility improvement, soil erosion control
21. CROP/GRASS SPECIES	banana, pepper, coffee, cassava, beans, cereals
22. LIVESTOCK SPECIES	
23. DATA SOURCE	farm survey, case studies, estimates

REFERENCES

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Hoekstra, D.A. and Van Gelder, A. (1985). *Annotated bibliography of economic analysis of agroforestry systems/technologies*. Working Paper No. 10. Second edition. Nairobi: ICRAF, 61 pp.

Jickling, J. (1989). *Short-term economic benefits of agroforestry: a survey*. Unpublished draft. Washington D.C.: USAID/USDA, Forestry Support Program, 36 pp.

Müller, E.U. and Scherr, S.J. (1989). *Technology monitoring and evaluation in agroforestry projects: an annotated bibliography*. Nairobi: ICRAF, 191 pp.

Swinkels, R.A. (1990). *Review of methods used for on-farm economic evaluation of agroforestry technologies*. Paper presented at the International Workshop on Methods for Participatory On-farm Research. Nairobi: ICRAF, 16 pp.

Upton, M. (1987). *African farm management*. Cambridge, UK: Cambridge University Press, 190 pp.

Westley, S.B. (1990). Living fences; a close look at an agroforestry technology. *Agroforestry Today*. 2(1): 11-13.

Bibliography

001
B
ABU, J.E. (1989)
RESOURCE PRODUCTIVITY IN TAUNGYA FARMS I: A CASE-STUDY OF GAMBARI FOREST RESERVE
Paper presented at the Forestry Research Institute of Nigeria, Agroforestry Forum, 27 Sept 1989
11 pp. EN XA/NG
ICRAF acc. no: 11055

The author examines resource-use efficiency in taungya farms in Nigeria. Input-output data are from a structured farm survey carried out in the area in 1982. These are used for two types of production-function analysis: a linear and a Cobb-Douglas (C-D) production function. Regression coefficients are calculated. The C-D function is then selected for further use because of a higher degree of multiple determination (0.74). Subsequently, marginal analysis is carried out by comparing the ratio of marginal output and marginal costs of land and labour. The marginal costs are rent cost for land and the wage rate for labour respectively. The ratio is 8.3 for land and 0.47 for labour. It is concluded that labour is not used efficiently and its input should be reduced by farmers. Output in the analysis refers to the gross value of the crops only.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: production-function analysis, regression analysis
ANALYSIS LEVEL: region
TECHNOLOGY: taungya afforestation
DATA SOURCE: farm survey

002
B
AGUIRRE, A. (1983)
A SILVICULTURAL AND ECONOMIC STUDY ON THE TAUNGYA SYSTEM IN THE TURRIALBA AREA
(Estudio Silvicultural y Económico del Sistema Taungya en las Condiciónes de Turrialba)
Reimpreso no. 196, Separado de Turrialba, Instituto Interamericano de Ciencias Agricolas, Costa Rica
Vol. 13 No. 3 pp. 168-171 ES XL/CR

Two different systems of reforestation are compared: the taungya system in which the planting of agricultural crops is combined with the planting of valuable timber trees, and the current system of reforestation, which does not involve the temporary use of the land for agriculture. In both systems, survival, initial growth of the forest species and costs of establishment are analysed. Four valuable timber species were used: laurel, cypress, mahogany and teak. The results indicate that teak and laurel are particularly suitable for reforestation by means of the taungya system. It is also found that the system is economically and socially desirable under local conditions.

ECOZONE: humid highlands
TYPE OF ANALYSIS: partial budgeting ex-ante
TECHNOLOGY: taungya afforestation
TREE/SHRUB SPECIES: *Cordia alliodora, Cupressus lusitanica, Swietenia humilis, Tectona grandis*
TREE/SHRUB PRODUCT: timber

003
A
AHMED, P. (1989)
EUCALYPTUS IN AGROFORESTRY: ITS EFFECT ON AGRICULTURAL PRODUCTION AND ECONOMICS
Agroforestry Systems
Vol. 8 pp. 31-38 EN XP/IN
ICRAF acc. no: 10477

The economics of eucalyptus in boundary plantings are studied, taking into account its effect on crops. Data are from 'observations' made during the harvests in agricultural fields and from information supplied by 'progressive farmers', but this method is not fully explained. Rotations of 8, 9, and 10 years of eucalyptus from a one acre-plot with 100 trees on its boundaries are compared. Costs and benefits are given for each of these, starting with the (unspecified) plantation costs. Wood returns are shown according to their different sizes after the rotation lengths. Crop losses due to shading are 8% in the 3rd and 4th year, 14% in the 5th and 6th year, 26% in the 7th and 8th year, and 45-49% in the 9th and 10th year. Because of very high crop losses in these last two years, the 8-year cycle gives the highest net returns. Benefit-cost ratios and net present values confirm this outcome. The internal rate of return is 47%, 38% and 31% for 8, 9, and 10 years rotations respectively.

ECOZONE: semi-arid
TYPE OF ANALYSIS: cost-benefit analysis ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: boundary planting
TREE/SHRUB SPECIES: *Eucalyptus tereticornis*
TREE/SHRUB PRODUCT: timber, pulpwood, fuelwood
CROP/GRASS: wheat, rice
DATA SOURCE: farm survey, case studies

004
A
AKACHUKU, A.E. (1985)
COST-BENEFIT ANALYSIS OF WOOD AND FOOD COMPONENTS OF AGRISILVICULTURE IN NIGERIAN FOREST AREAS
Agroforestry Systems
Vol. 3 pp. 307-316 EN XA/NG
ICRAF acc. no: 6088

Costs and revenues of a planted tree fallow in the Nigerian forest zone of Cross River State are calculated. Two crop combinations are considered for intercropping with *Gmelina arborea Roxb.*: (a) yam and maize, and (b) cassava and maize. Gmelina seedlings were planted at a spacing of 2.44 x 2.44m. Trees were planted with the cassava, after planting of yam and maize. Gmelina was harvested after 5 years, providing a 3-4 year fallow to restore soil fertility. The author concludes that such intercropping/fallow systems would be very profitable to the farmer. The study provides a detailed breakdown of costs, benefits and management over time, but results are difficult to interpret due to exclusion of non-cash costs, opportunity costs and other factors. Data used in the analysis were based on a study of average costs and revenues from wood and food in five forest reserves of the study area.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: cost-benefit analysis ex-post
ANALYSIS LEVEL: farm, region
TECHNOLOGY: improved tree fallow, trees mixed in annual cropland
TREE/SHRUB SPECIES: *Gmelina arborea*
TREE/SHRUB PRODUCT: fuelwood, poles, stakes
TREE/SHRUB SERVICE: soil conservation
CROP/GRASS: yam, maize, cassava
DATA SOURCE: unspecified

005
A
ALVAREZ-BRYLLA, M.E.; LAZOS-CHAVERO, E.; GARCIA-BARRIOS J.R. (1989)
HOMEGARDENS OF A HUMID TROPICAL REGION IN SOUTHEAST MEXICO: AN EXAMPLE OF AN AGROFORESTRY CROPPING SYSTEM IN A RECENTLY ESTABLISHED COMMUNITY
Agroforestry Systems
Vol. 8 pp. 133-156 EN XL/MX
ICRAF acc. no: 10347

This paper describes and analyzes the major components of the process of production in homegardens in southeast Mexico. Management tasks, means of production, and the amount, quality, and temporal distribution of the products are discussed. Detailed analysis is presented of functional differences in eight homegardens and the roles they play in the economic organization of peasant families. Data are presented on labour inputs for different functional areas of the homegarden, value of technological inputs, consumption, and sale of homegarden products during the years. The extent and magnitude of the economic advantages of homegardens vary among peasant families, depending upon the level of structural complexity and its size. The largest and most diverse homegardens are found in families with few productive alternatives, and those in a strong and stable economic situation (although the latter have more ornamental and fewer food-producing crops). The authors conclude that expansion of homegardens could take place with 1) the activation and expansion of markets for homegarden products, or 2) the transformation of the family economy towards self-subsistence.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: partial budgeting ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: trees in homegarden
LIVESTOCK: pigs, poultry
DATA SOURCE: farm survey, case studies

006
B
ANDERSON, D.; FISHWICK, R. (1984)
FUELWOOD CONSUMPTION AND DEFORESTATION IN AFRICAN COUNTRIES
World Bank Staff Working Papers No. 704. Washington D.C.: The World Bank
52 pp. EN XA
ICRAF acc. no: B3342

The authors review recent reports on the level and growth of fuelwood consumption in Africa, and on the ecological, economic and possible micro-climatic effects of deforestation. They suggest the economic and operational aspects of policies open to governments i.e.: (i) to encourage fuelwood conservation, (ii) to facilitate the substitution of commercial energy for fuelwood, where desirable on grounds of relative costs, (iii) to develop the traditional functions of the forestry services in maintaining the forest reserves and undertaking plantings in watersheds and shelterbelts, and (iv) to promote the practice of agroforestry, i.e. the planting and maintenance of trees in cropland and around farms by the farm families themselves. All four are important, but it is argued that agroforestry offers considerable promise in terms of increased planting rates, low budgetary requirements, ecological benefits and good economic and financial rate of return. The importance of the 'policy environment' for the success of each is also discussed, as are the various research, education, training and other requirements of agroforestry.

TYPE OF ANALYSIS: agroforestry sector analysis
TREE/SHRUB PRODUCT: fuelwood
DATA SOURCE: unspecified, farm survey, estimates

007
A
ANDERSON, D. (1987)
THE ECONOMICS OF AFFORESTATION: A CASE STUDY IN AFRICA
World Bank Occasional Papers No. 1. London: Johns Hopkins University Press
86 pp. EN XA/NG
ICRAF acc. no: B4858

This paper offers a comprehensive approach to cost-benefit analysis for agroforestry interventions on a regional level. Its objective is to illustrate the substantial economic benefits which can be expected from shelterbelts and farm forestry in semi-arid agricultural regions of Africa. The agroforestry technologies

referred to as 'farm forestry' are not specified, making cost-benefit estimates rather speculative. A case study is presented for northern Nigeria, based on project experience. The author evaluates benefits in terms of changes in soil fertility, crop production, wood and fruit production, and livestock production calculated for the region. Response curves are generated for gross and net benefits over time. The author identifies key information needed from foresters, agriculturalists and social scientists to overcome existing limitations of the model due to lack of data. The data consist of country and project estimates.

ECOZONE: semi-arid
TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm, region
TECHNOLOGY: windbreak, woodlot
TREE/SHRUB SPECIES: *Eucalyptus spp, Azadirachta indica*
TREE/SHRUB SERVICE: wind protection, soil fertility improvement
CROP/GRASS: millet, sorghum, cowpea, groundnut
DATA SOURCE: estimates

008
B
ANDERSON, G.W.; MOORE, R.; JENKINS, P.J. (1988)
THE INTEGRATION OF PASTURE, LIVESTOCK, AND WIDELY-SPACED PINE IN SOUTHWESTERN AUSTRALIA
Agroforestry Systems
Vol. 6 pp. 195-211 EN XP/AU
ICRAF acc. no: 10273

The integration of pine, pasture and grazing has been extensively studied in western Australia since 1973. This paper outlines methods of managing an agroforestry system, summarizes data from trials, and presents the major findings of the economic analysis. Combined productivity is higher in agroforestry than in either enterprise on its own. Additional benefits are obtained from wind protection, shade, shelter for livestock, soil erosion control, reduced waterlogging and salinity, and fodder production from needles. Although agroforestry was found to be more profitable in the long term than a grazing enterprise, the distribution of income is less favourable in the short term and there is a higher labour requirement. Costs of establishing and tending trees must be met at a time when grazing income is declining. Various solutions to these problems are suggested. Agroforestry may be more suitable than plantation forestry for the farmer who is far from markets because it is more economic to transport higher quality logs. Growers can time harvesting to suit their financial needs.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante and ex-post, agroforestry sector analysis
ANALYSIS LEVEL: region, farm, research plot
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Pinus radiata, Pinus pinaster*

TREE/SHRUB PRODUCT: timber, fodder
TREE/SHRUB SERVICE: shade
LIVESTOCK: sheep, goats, cattle
DATA SOURCE: research plot

009
B
APPLEGATE, G.B.; NICHOLSON, D.I. (1988)
CARIBBEAN PINE IN AN AGROFORESTRY SYSTEM ON THE ATHERTON TABLELAND IN NORTH EAST AUSTRALIA
Agroforestry Systems
Vol. 7 pp. 3-15 EN XP/AU
ICRAF acc. no: 12020

This paper presents the results of trial establishment of pine mixed in grasslands on one farm in northern Australia's Atherton tableland. Details on plot establishment, management and harvest are presented, and problems in these areas are identified. Production costs and returns up to 39 months are analysed, and subsequent expected income estimated. The authors conclude that with appropriate technical support, this system is economically attractive.

ECOZONE: humid
TYPE OF ANALYSIS: partial budgeting ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Pinus caribaea*
TREE/SHRUB PRODUCT: timber
LIVESTOCK: cattle
DATA SOURCE: research plot, case studies

010
A
ARIZA-NIÑO, E.J. (1983)
LIVESTOCK AND AGROFORESTRY IN PEASANT FARMS OF AFRICA - ILLUSTRATIVE MODELLING AND METHODOLOGY
Unpublished draft. Nairobi: ICRAF and Ann Harbor, Michigan, USA: University of Michigan, Centre for Research on Economic Development
40 pp. EN XA/NE
ICRAF acc. no: 9968

Before farmers can be encouraged to incorporate tree planting into their enterprises, it first needs to be determined whether the benefit to the farmer will indeed in the long run compensate for the initial financial and labour effort required to establish the trees. For this purpose a farm model was constructed with input-output data based on a village study in southern Niger. It included eight cropping, three livestock, and one (new) agroforestry activity. The latter consists of a 1 ha fodder bank for cattle, harvested from years 3-7 with 1 ton per ha per year and intercropped during the first 2 years. The yearly resource requirements and

output valuations included in the model lead to the annual optimal farm plans. The net present values (NPV) per ha over the 7-year period with and without leucaena fodder banks are almost the same (CFA 3.058 million and 2.967m respectively), but the author regards the difference as significant. The optimal size of the tree plot giving the highest NPV is determined by a trial and error method. Labour use data are not included; nutritional requirements are based on data from the USA.

ECOZONE: semi-arid lowlands
TYPE OF ANALYSIS: linear programming
ANALYSIS LEVEL: farm
TECHNOLOGY: fodder bank
TREE/SHRUB SPECIES: *Leucaena leucocephala*
TREE/SHRUB PRODUCT: fodder
LIVESTOCK: cattle
CROP/GRASS: millet, sorghum, groundnut
DATA SOURCE: case studies

011
A
ARNOLD, J.E.M. (1983)
ECONOMIC CONSIDERATIONS IN AGROFORESTRY PROJECTS
Agroforestry Systems
Vol. 1 pp. 299-311 EN XZ
ICRAF acc. no: 4060

This paper reviews the economic benefits that can accrue to the small farmer from incorporating trees in his farm system, and the economic constraints and costs he may face in doing so. Economic factors include considerations of risk, as well as cash outlays and income. Issues that arise in designing and implementing projects to help farmers to capture economic potentials of agroforestry and to avoid or remove economic impediments are discussed. Factors highlighted include valuation of the costs and benefits of trees as perceived by farmers, distributional and equity issues, and the need for short term economic benefits. The author concludes by emphasizing the need for research on the economic impacts of agroforestry practices on small farmer situations. The paper is an excellent overview of the challenges posed in economic evaluation of agroforestry in smallholder systems.

TYPE OF ANALYSIS: economic concepts/methodology, agroforestry sector analysis

012
A
ARNOLD, J.E.M. (1987)
ECONOMIC CONSIDERATIONS IN AGROFORESTRY
In K. Steppler and P.K. Nair (eds) *Agroforestry: A Decade of Development.* Nairobi: ICRAF
pp. 174-190 EN XZ/KE/PH/IN
ICRAF acc. no: 8295

The results of economic studies of well-established homegardens in Java (Indonesia), eastern Nigeria and Kerala (India) are reviewed. Situations in which trees are planted as farmer cash crops in parts of the Philippines, India and Kenya are examined for their economic value and problems. One general conclusion is that the cultivation of trees is increasing in most cases at a time of heightening pressures on the farmers' resources of land, labour or capital. The growing importance of income-generating activities suggests the importance of more research on markets and cash-generating agroforestry products. The study provides clear analyses of markets and marketing, risk management, labour availability and requirements, and further economic constraints and opportunities for adoption of agroforestry technologies among farmers.

TYPE OF ANALYSIS: economic concepts/methodology, agroforestry sector analysis
ANALYSIS LEVEL: region, farm
TECHNOLOGY: trees in homegarden, woodlot, hedgerow intercropping
TREE/SHRUB SPECIES: *Faidherbia (acacia) albida, Sesbania sesban, Acacia senegal, Leucaena leucocephala, Albizia falcataria*
DATA SOURCE: unspecified

013
A
ARTHUR-WORSOP, M.J. (1984)
AN ECONOMIC EVALUATION OF AGROFORESTRY: THE NATIONAL VIEWPOINT
In G.W. Bilbrough (comp) *Proceedings of a Technical Workshop on Agroforestry.* New Zealand Forest Service
pp. 61-70 EN XP/NZ
ICRAF acc. no: 10961

A comparison is made between a silvipastoral system (sheep and timber) and a pastoral system for four trial sites in New Zealand. Timber yields were estimated with a computer program called SILMOD. It was found that the best timber results were obtained with a final stand of 100 trees/ha. Graphics on the effect of different tree densities on sheep carrying capacities over a period of 30 years are provided. Although the pastoral benefits within the silvipastoral system are lower than in the pure pastoral system, overall net benefits from the silvipastoral system were higher.

TYPE OF ANALYSIS: cost-benefit analysis ex-ante, computer program
ANALYSIS LEVEL: research plot
TECHNOLOGY: fodder bank
TREE/SHRUB SPECIES: *Pinus spp*
TREE/SHRUB PRODUCT: timber
LIVESTOCK: sheep

014
A
AVILA, M. (1989)
ECONOMIC EVALUATION OF ALLEY FARMING
IITA/ILCA/ICRAF Training Course on Alley Farming for Tropical Africa.
Ibadan, Nigeria: International Institute of Tropical Agriculture
20 pp. EN XZ
ICRAF acc. no: 10132

This paper has been presented for a training course. It provides a basic framework and concepts for economic evaluation of a new technology introduced in a new system. The author stresses that this requires a clear definition of the target farming system, and a clear understanding of the goals, objectives, and priorities of the decision maker in a household. A practical example is given with hypothetical data comparing three cropping systems: 1) traditional maize-beans, 2) improved maize-beans 3) hedgerow intercropping with maize-beans. Data on yield, labour use, other inputs, result in a single-year farm budget. It shows that the traditional system is more profitable for most of the indicators (return per input) except for gross return per cash input. The need for a comparison with monthly labour availability is shown. Risk analysis is carried out showing expected net income. The cost of the hedge is introduced as the depreciation of its investment. Finally, a multi-annual cost-benefit analysis is presented. It shows that alley farming has a higher net present value and internal rate of return due to the present decline in soil fertility in the traditional cropping system.

TYPE OF ANALYSIS: economic concepts/methodology, partial budgeting ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: hedgerow intercropping
TREE/SHRUB SPECIES: *Leucaena leucocephala*
TREE/SHRUB PRODUCT: mulch, fodder
TREE/SHRUB SERVICE: soil-fertility improvement
CROP/GRASS: maize, beans
DATA SOURCE: estimates

015
A
BAAH-DWOMOH, J. (1983)
ESTIMATING STUMPAGE VALUE OF WOOD IN THE SAHEL
World Bank Working Paper. Washington D.C.: The World Bank
12 pp. EN XA/ML/NE/SN
ICRAF acc. no: 4401

Although fuelwood prices have increased in the Sahel in the last decade, this is mainly attributed to increases in labour and transportation costs and the profits of loggers. However, there has been no increase in the stumpage value of wood. It is argued that stumpage prices be raised to cover the real costs of introduction of trees. Stumpage value calculations are presented for Mali, Senegal and Niger.

ECOZONE: semi-arid
TYPE OF ANALYSIS: agroforestry sector analysis
ANALYSIS LEVEL: country
TECHNOLOGY: woodlot
TREE/SHRUB PRODUCT: fuelwood, poles, timber

016
A
BALASUBRAMANIAN, V. (1983)
ALLEY-CROPPING: CAN IT BE AN ALTERNATIVE TO CHEMICAL FERTILIZERS IN GHANA?
Third National Maize Workshop. Kumasi, Ghana: Kwadeso Agricultural College
21 pp. EN XA/GH
ICRAF acc. no: 3159

Yam-leucaena and maize/cowpea-leuceana alley-cropping systems are described. Observations under Atebubu (Ghana) trial conditions for the dry year of 1982 indicate that yam tuber yield is reduced due to serious shading of yam foliage by live-stakes and that the maize grain yield in leucaena plots is also lower than that in sole maize plots possibly due to the reduction in area planted to maize and the intercrop competition for moisture in such dry years. When compared to the sole crop systems, the labour requirement appears to be 17% higher for the yam-leucaena and 8% higher for the maize-leucaena systems during the early stages due to extra labour needed for leucaena establishment. In later stages, however, the labour required for hedge pruning will be compensated for by less weeding needed in the cropped alleys. The need for machinery for pruning leucaena is mentioned. The study gives detailed labour and yield data.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: partial budgeting ex-ante and ex-post, economic concepts/methodology
ANALYSIS LEVEL: farm
TECHNOLOGY: hedgerow intercropping
TREE/SHRUB SPECIES: *Leucaena leucocephala*
TREE/SHRUB PRODUCT: mulch
TREE/SHRUB SERVICE: soil-fertility improvement
CROP/GRASS: maize, yam, cowpea
DATA SOURCE: research plot

017
A
BALL, J. (1977)
TAUNGYA IN SOUTHERN NIGERIA
Rome: FAO
24 pp. EN XA/NG
ICRAF acc. no: 0985

Taungya systems as practised in the forest reserves in Southern Nigeria are discussed. Three systems are compared: departmental taungya (food crop grown by the Forest Department), traditional taungya (food crop grown by farmers) and direct planting (no food crop grown). Intercropping with annuals takes place for two years while teak is grown on a 60-year rotation and gmelina over two 15-year rotations. The disadvantage of traditional taungya is poor stocking of trees due to poor discipline among farmers, while disadvantages of department taungya are low agricultural yields and high supervisory costs. A cost/benefit analysis of each system is conducted from the point of view of the Forest Department only.

ECOZONE: sub-humid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: region, farm, plantation
TECHNOLOGY: taungya afforestation
TREE/SHRUB SPECIES: *Tectona grandis, Gmelina arborea*
TREE/SHRUB PRODUCT: timber
CROP/GRASS: maize, yam, cassava, vegetables
DATA SOURCE: farm survey

018
B
BARBIER, E.B. (1990)
ECONOMICS FOR SUSTAINABLE PRODUCTION
In R.T. Prinsley (ed) *Agroforestry for Sustainable Development: Economic Implications.* London: Commonwealth Science Council
pp. 389-404 EN XZ
ICRAF acc. no: 11638

The author proposes an operational definition of 'sustainable development' as maintaining the constancy of natural capital. The paper demonstrates how a 'weak' and 'strong' sustainability criterion can be incorporated into cost-benefit analysis. The economic efficiency objective is modified to mean that all projects yielding net benefits should be undertaken subject to the requirement that environmental damage (i.e. natural capital depreciation) should be zero or negative. If applied at the individual project level, such an approach would be too restrictive. At the programme level, however, it could be interpreted as saying that netted out across a set of projects, the sum of individual damages should be zero or negative. A programme would attempt to balance environmentally depleting projects against environmentally compensating projects. The author suggests that under such a scheme, far more agroforestry projects would be found to be acceptable investments (i.e. environmentally compensating).

TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-ante and ex-post (economic)
ANALYSIS LEVEL: farm, project, region
TREE/SHRUB SERVICE: soil conservation, soil-fertility improvement

019
B
BEALE, C.I.A. (1980)
ECONOMIC ASPECTS OF DEVELOPING LEUCAENA AS A CASH CROP: A REVIEW OF PRE-INVESTMENT STUDIES IN MALAWI, 1974-1979
In H.N. Le Houerou (ed) *Browse in Africa.* Addis Ababa: International Livestock Centre for Africa
pp. 419-423 EN XA/MW
ICRAF acc. no: B0631

This paper evaluates the preliminary results of a study on the commercial prospects for leucaena growing on an industrial scale in lower Shire valley, Malawi. The domestic and international market prospects are explored, concluding that the first one is small and exports are feasible. Processing experiments derived from trials (on-farm and on-station) conclude that pelleting of leucaena leaves is essential to minimize transport costs and that woody parts of the plant could provide the energy necessary for drying. Production on small farms is not feasible due to high cost of the necessary goat-proof fencing. Average yield from nine smallholdings (0.2 hectare plots) are presented. Establishment costs are given for larger blocks partially with machinery, as well as labour costs of harvesting, threshing, sieving and bagging. Self-employed labourers had more than double the output of daily paid labourers (67 manhours to cut one ha of trees vs. 149 person-hours). Daily record keeping of all labour inputs led to calculation of yield per manday, which however, varied widely. Settlement schemes in the form of a nucleus estate are proposed to achieve economics of scale. With no value attached to labour US$ 153/ha would be the gross margin for a smallholder.

ECOZONE: sub-humid
TYPE OF ANALYSIS: partial budgeting ex-ante
ANALYSIS LEVEL: farm, plantation
TECHNOLOGY: woodlot
TREE/SHRUB SPECIES: *Leucaena leucocephala*
TREE/SHRUB PRODUCT: fodder
DATA SOURCE: research plot, case studies

020
B
BERENSCHOT, L.M. (1986)
AN AGROFORESTRY SYSTEM WITH ACACIA MEARNSII IN ITS SOCIO-ECONOMIC CONTEXT: A CASE STUDY IN THE RURAL UPLANDS OF CENTRAL JAVA
Communication 1986-9, Forest/Nature Conservation Project. Yogyakarta, Indonesia: Gadjah Mada University
98 pp. EN XP/ID ICRAF acc. no: 6985

This study deals with an agroforestry system in central Java and presents results of a survey of 10% of households in five selected villages. Data on the history of *Acacia mearnsii* production and physical and socio-economic characteristics of the villages are given. Distribution, cultivation techniques, and yields of *A. mearnsii* are evaluated. Financial returns to farmers from fuelwood and bark sales of black wattle, as well as the financial value of soil improvement through black wattle planting are estimated, and compared to estimated returns from cropping. It appears no longer highly profitable relative to cash crop production. Factors associated with *A. mearnsii* planting were identified, including larger farm size, lower reliance on cash markets, and lower population densities. Site characteristics played a less important role. The author identifies economic alternatives for farmers in terms of cash income and fuelwood supply.

ECOZONE: humid highlands
TYPE OF ANALYSIS: agroforestry sector analysis
ANALYSIS LEVEL: farm
TECHNOLOGY: woodlot, trees mixed in annual cropland, improved tree fallow, taungya afforestation
TREE/SHRUB SPECIES: *Acacia mearnsii*
TREE/SHRUB PRODUCT: fuelwood, timber, tannin
TREE/SHRUB SERVICE: soil-fertility improvement
CROP/GRASS: tobacco, maize
DATA SOURCE: farm survey, estimates

021
B
BERENSCHOT, L.M.; FILIUS, A.M.; HARDJOSOEDIRO, S. (1988)
FACTORS DETERMINING THE OCCURRENCE OF THE AGROFORESTRY SYSTEM WITH *ACACIA MEARNSII* IN CENTRAL JAVA
Agroforestry Systems
Vol. 6 pp. 119-135 EN XP/ID
ICRAF acc. no: 8408

This paper evaluates the future prospects for agroforestry based on black wattle in Wonosobo, Java, Indonesia, a system first introduced in 1922. Results of a survey of 143 farmers in 5 villages are reported. Several factors affect *A. mearnsii* growing: population density (which affects farm size and demand for domestic tobacco), tobacco processing (which requires fuel), topography and commercialization. The system has declined in importance in recent years. The

gross margin of *A. mearnsii* is probably not as high as that of the main subsistence and cash crops in the region. Higher demand for fuelwood may be met from other resources or fuelwood substitutes, and the fertility improvement function may increasingly be met through purchased fertilizers. The authors support the hypothesis that as population pressure increases, the intensity of the multiple cropping of food crops and trees first increase, but then decrease again in favour of staple food crops after a certain threshold value has been reached.

ECOZONE: humid highlands
TYPE OF ANALYSIS: agroforestry sector analysis
ANALYSIS LEVEL: region, community
TECHNOLOGY: improved tree fallow, woodlot, taungya afforestation, trees mixed in annual cropland
TREE/SHRUB SPECIES: *Acacia mearnsii*
TREE/SHRUB PRODUCT: fuelwood, tannin
TREE/SHRUB SERVICE: soil conservation, soil-fertility improvement
CROP/GRASS: tobacco, maize, potato
DATA SOURCE: farm survey, estimates

022
B
BETTERS, D.R. (1988)
PLANNING OPTIMAL ECONOMIC STRATEGIES FOR AGROFORESTRY SYSTEMS
Agroforestry Systems
Vol. 7 pp. 17-31 EN XZ
ICRAF acc. no: 9969

The author elaborates on the use of several economic concepts and analytical tools and how they are linked together in the agroforestry land-use planning process. The different steps to be taken in agroforestry land-use planning are presented. In the last phase economic analysis is needed to determine the optimal combination of trees and crops. The costs, benefits and their valuation at the village level in such an analysis are identified. An example is presented of how to choose the economically optimal combination of a certain tree and crop. Production possibility curves of a combination of eucalyptus and vegetables are shown for four cost levels, each one showing the point with the highest net present value (NPV). The issue of how to select the proper discount rate for the calculation of the NPV is treated. Bringing in other constraints and requirements, linear programming is carried out for a simplified hypothetical example, involving one three-year rotation for eucalyptus with maize or beans. The outcome is a combination of maize/eucalyptus and beans/eucalyptus. The basis for the assumptions made is not specified.

TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-ante, linear programming
ANALYSIS LEVEL: community, farm
TECHNOLOGY: trees mixed in annual cropland
TREE/SHRUB SPECIES: *Eucalyptus spp*

TREE/SHRUB PRODUCT: fuelwood
CROP/GRASS: beans, maize
DATA SOURCE: estimates

023
B
BIRD, P.R. (1988)
FINANCIAL GAINS OF TREES ON FARMS THROUGH SHELTER
Unpublished draft
11 pp. EN XP/AU
ICRAF acc. no: 9855

An ex-ante economic analysis was made of eight design options for shelterbelts and woodlots on large sheep farms in Australia. Benefits identified were income from timber, improved lamb and sheep survival, increased pasture production, and increased sheep growth through reduction of stress from wind and sun. Economic returns for the different options were compared at five discount rates, and sensitivity to reduction in expected benefits was assessed. The study concludes that 10% of a farm can be devoted to shelterbelts/woodlots without depressing economic returns from agriculture. Long term average income in the higher rainfall zones of southern Australia would actually be increased by devoting up to 20% of the farm to strategically placed shelterbelts and woodlots.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: windbreak, woodlot
TREE/SHRUB SPECIES: *Eucalyptus cladocalyx, Eucalyptus camaldulensis, Pinus radiata, Acacia melanoxylon*
TREE/SHRUB PRODUCT: timber
TREE/SHRUB SERVICE: wind protection, shade
LIVESTOCK: sheep
DATA SOURCE: estimates, research plot

024
A
BLANDON, P. (1984)
AGROFORESTRY AND PORTFOLIO THEORY
Agroforestry Systems
Vol. 3 pp. 239-249 EN XZ
ICRAF acc. no: 5399

Portfolio theory defines how to diversify a portfolio of stocks in an optimum way with regard to risk and returns. In agroforestry this is of relevance in choosing the mixture of species to cultivate, which fits in a farmers' strategy to minimize risk and maximize returns. Risk is defined by the author as the standard deviation of the revenues expected. For two components in an agroforestry system this is defined by an equation using their covariance, and depends on their correlation

coefficient. Graphic examples are given of returns with different risks, for which the correlation coefficients are -1, 1, and 0. If it lies between -1 and 1, a convex line results, the upper part of which shows efficient and optimal combinations of different risks and returns. The same analysis is done for tree components. It is shown that introducing a forestry component whose returns are unrelated to the returns of the two crops can help to reduce risk. In a practical situation the crucial point is to estimate the covariance between crops.

TYPE OF ANALYSIS: economic concepts/methodology
ANALYSIS LEVEL: farm

025
B
BOSE, R.K.; BANDOYOPADHYAY (1986)
ECONOMICS OF ENERGY PLANTATIONS IN ALKALI SOILS OF INDIAN SEMI-ARID REGIONS
Biomass
Vol. 11 pp. 51-60 EN XP/IN
ICRAF acc. no: 9846

About 40% of the barren salt-affected soils of India (2.8 million hectares) are found in the Indo-Gangetic plains in the States of Uttar Pradesh, Haryana and Punjab. The principal constraint that reduces the productivity of such soils is soil salinity. Therefore, a field experiment was conducted under controlled conditions of seven fast-growing selected tree species. The trial was located on a 4.7 ha plot of salt-affected community land at Dhanawas village, Gurgaan district, Haryana. This paper attempts to: (1) identify suitable fast growing species capable of withstanding a high level of alkalinity, which will primarily be used for providing firewood and (2) examine the economic feasibility of afforestation technology in these salt-affected soils.

TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: research plot
TECHNOLOGY: woodlot
TREE/SHRUB SPECIES: *Prosopis juliflora, Acacia nilotica, Eucalyptus spp, Dalbergia sissoo, Leucaena leucocephala, Azadirachta indica, Albizia lebbeck*
TREE/SHRUB PRODUCT: fuelwood
DATA SOURCE: research plot

026
B
BRADLEY, P. (1990)
'IF I HAD KNOWN THE DISCUSSION WAS TO BE ABOUT KUNI I WOULDN'T HAVE WASTED MY TIME COMING'
In R.T. Prinsley (ed) *Agroforestry for Sustainable Production: Economic Implications.* London: Commonwealth Science Council
pp. 123-146 EN XA/KE
ICRAF acc. no: 11563

The author presents case studies of early patterns of agroforestry adoption for fuelwood production in the Kenya Woodfuel Development Programme. He examines two communities in the densely populated districts of Kakamega and Kisii, and two individuals in order to draw more general conclusions about farmer incentives and their implications for agroforestry development programmes. Strong gender roles excluded women from decision-making about trees, even when they were interested and men were non-resident. Free distribution of seed defined the activity as worthless. Contact farmers with 'average' resources were much more effective demonstrations of new technology, than 'well-off' farmers. The author states that in areas where households depend upon the market, agroforestry inputs and outputs must be assessed in market values. He recommends community and regional historical analysis as part of project planning and a focus on private returns in privatized farming areas rather than a community conservation focus.

ECOZONE: humid highlands
TYPE OF ANALYSIS: agroforestry sector analysis
ANALYSIS LEVEL: farm, community
TECHNOLOGY: hedgerow intercropping, trees mixed in annual cropland, fodder bank, woodlot
TREE/SHRUB SPECIES: *Sesbania sesban, Leucaena leucocephala, Calliandra calothyrsus, Grevillea robusta, Mimosa scabrella, Acacia mearnsii, Eucalyptus saligna, Croton macrostachys, Cupressus lusitanica*
TREE/SHRUB PRODUCT: fuelwood, poles, fodder, tannin
TREE/SHRUB SERVICE: soil-fertility improvement
LIVESTOCK: cattle
DATA SOURCE: case studies, farm survey

027
B
BRECHIN, S. (1984)
REVIEW OF AGROFORESTRY PROJECT DATA
In K. Shapiro (ed) *Agroforestry in Developing Countries*. Ann Arbor, USA: University of Michigan
pp. 145-176 EN XZ
ICRAF acc. no: B2371

This paper presents the results of an extensive review of quantitative data on benefits and costs in agroforestry projects. Data are presented from many tropical countries on timber production, income, soil improvement, and environmental protection. Figures are taken from a wide range of agroforestry practices, although taungya and windbreaks dominate. The data were compiled to facilitate ex-ante cost-benefit analysis by providing information on which to base rough approximations of likely levels of benefits and costs.

TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm, project, plantation
DATA SOURCE: unspecified

028
B
BRODER, J.M.; ODRONIC, B.H. (1988)
ECONOMIC POTENTIAL OF AGROFORESTRY FOR PUBLIC RECREATIONAL PARKS
Agroforestry Systems
Vol. 10 pp. 99-112 EN US/XN
ICRAF acc. no: 11701

Agroforestry enterprises indigenous to the area were selected for development on 70 ha of a recreational park, in order to supplement its revenue. Linear programming was used to determine the optimum combinations of 23 agroforestry regimes composed of the following activities: 1) conventional forestry planting, tree density 1682 trees per ha, 2) agroforestry planting with hay, tree density 1495 per ha, 3) agroforestry planting with grazing, 4) hay production only, and 5) rental of pasture for grazing. The objective function of the model was to maximize the net present value of the study site subject to land, labour, capital, and minimum annual income constraints. The preferred optimal regime generated $1782 per ha from an agroforestry planting configuration of 1495 trees per ha with 75% hay, 25% grazing, and no minimum annual income requirements. Minimal annual income requirements of $2400 and $4800 were feasible but suboptimal from a net present value criteria. Data were derived from publications of the Agricultural Extension Service of the University of Georgia.

ECOZONE: temperate
TYPE OF ANALYSIS: linear programming
ANALYSIS LEVEL: plantation
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Pinus spp*
TREE/SHRUB PRODUCT: timber
LIVESTOCK: cattle
DATA SOURCE: estimates, unspecified

029
A
BROMLEY, D. (1981)
THE ECONOMICS OF SOCIAL FORESTRY: AN ANALYSIS OF A PROPOSED PROGRAM IN MADHYA PRADESH, INDIA
Unpublished draft. Madison, USA: University of Wisconsin
53 pp. EN XP/IN
ICRAF acc. no: 3827

The author argues that the feasibility of a program for social forestry should be looked at not only from the village point of view, but also from the point of view of the Forest Department, the state and the central government. Several multipurpose plantation models (providing grass, fodder, fuel, timber, fruit, pods, and poles) are proposed for villages in Madhya Pradesh. Each village has its own mixture of trees depending on the villagers' preference. Detailed technical and economic data are provided for each model. The effect each model has on each of

the aforementioned 'project actors' is examined in detail. This includes a social cost/benefit analysis from the public sector point of view.

ECOZONE: semi-arid lowlands
TYPE OF ANALYSIS: cost-benefit analysis ex-ante (economic)
ANALYSIS LEVEL: community, region
TECHNOLOGY: woodlot
TREE/SHRUB SPECIES: *Eucalyptus spp, Gmelina arborea, Acacia spp, Prosopis juliflora, Ziziphus jujuba*
TREE/SHRUB PRODUCT: fodder, fuelwood, fruit, poles
LIVESTOCK: cattle
DATA SOURCE: estimates, unspecified

030
B
BROOK, B.A. (1973)
GRASS UTILIZATION DURING FOREST ESTABLISHMENT
New Zealand Journal of Forestry
Vol. 18 No. 1 pp. 141-147 EN XP/NZ
ICRAF acc. no: 1728

Alternative systems of growing and harvesting grass during the establishment phase of trees and their comparative economics are evaluated for an area where contour permits the use of farm machinery. The establishment period is taken as three years from planting, assuming that after this period the area may be grazed by cattle without fear of damaging the trees. The systems of utilization considered are the making of hay or silage, and the cutting and carting of fresh grass. After allowing for such factors as the area covered by trees, the loss of fertility, efficiency of utilization of the grass grown, costs of harvesting and feeding out, the value of the grass grown is assessed in each of the three years. The profit margins are: $24.30/ha in year one, break even in year two and a loss of $17.30/ha in year three.

ECOZONE: temperate
TYPE OF ANALYSIS: partial budgeting ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: trees in pasture
LIVESTOCK: cattle
DATA SOURCE: estimates

031
A
BROOKS, K.N.; GREGERSEN, H.M. (1985)
THE ECONOMICS OF WATERSHED MANAGEMENT - PROBLEMS AND RECOMMENDATIONS FOR PROJECT ANALYSIS
Background paper for the Experts Consultation on Strategies, Approaches and Systems for Integrated Watershed Management, 25 Feb-1 March 1985, Kathmandu
32 pp. EN XP ICRAF acc. no: 4533

The authors argue that watershed managers and scientists have not effectively demonstrated the economic and financial feasibility and benefits of watershed projects and management programmes. This paper examines the economic aspects of watershed management projects and illustrates and develops an understanding of the benefits derived from such projects, which is of relevance to agroforestry projects. It also looks at the problems of watershed analyses and considers ways in which such analyses can be performed more effectively and presented better to decision-makers. Such an approach involves: clearly defining the economic input-output relationships, social benefits and environmental attributes under 'with and without' watershed project conditions; calculating measures of project worth that are relevant to decision-makers; developing estimates of the impacts and nature of uncertainty and intangible benefits and costs. No numerical data are presented.

TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-ante (economic)
ANALYSIS LEVEL: country
TREE/SHRUB SERVICE: soil conservation

032
B
BURBRIDGE, P.; DIXON, P.; SOEWARDI, B. (1981)
FORESTRY AND AGRICULTURE: OPTIONS FOR RESOURCE ALLOCATION IN CHOOSING LANDS FOR TRANSMIGRATION DEVELOPMENT
Applied Geography
No. 1 pp. 237-258 EN XP/ID
ICRAF acc. no: 3428

This paper concentrates on questions of resource allocation in choosing sites for transmigration development. It is based on the hypothesis that ample land resources are available and that of the three main ecosystems used, i.e. tidal swamp forests, mature upland forest, and alang-alang (*Imperata cylindrica*) grasslands, the economic opportunity costs of using forested land can be considerable. The net present values of the options for the development of new agricultural sites or sustained-yield forestry are calculated. It is suggested that both forestry *and* agriculture can be developed. Development of alang-alang grasslands is to be preferred because it avoids the loss of long-term benefits that can be derived from well-managed forest.

ECOZONE: humid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: country
TECHNOLOGY: trees in pasture, woodlot
DATA SOURCE: estimates, unspecified

033
A
BURGESS, R.J. (1981)
THE INTERCROPPING OF SMALLHOLDER COCONUTS IN WESTERN SAMOA: AN ANALYSIS USING MULTI-STAGE LINEAR PROGRAMMING
MADE Research Series No. 4. Canberra: The Australian University, Development Studies Centre
162 pp. EN XP/WS
ICRAF acc. no: B0004

Multi-stage linear programming is used to model and optimize a coconut-based intercropping system for small farmers in Western Samoa. A modern systematic intercropping system is investigated for its technical and economic feasibility as a means of providing rural family cash income in competition with alternative sources. Other methods are used for optimising multi-period cropping systems. The model considers pineapple, cocoa, banana and taro as understorey crops. Detailed input/output, labour and cost data are provided for the mixtures as well as for the individual crops.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: linear programming
ANALYSIS LEVEL: farm
TECHNOLOGY: trees mixed in annual cropland
TREE/SHRUB SPECIES: *Cocos nucifera, Theobroma cacao*
TREE/SHRUB PRODUCT: fruit
CROP/GRASS: banana, cocoyam
DATA SOURCE: unspecified, estimates, farm survey

034
B
CAMPBELL, G.E.; LOTTES, G.J.; DAWSON, J.O. (1989)
AN ANALYSIS OF AGROFORESTRY SYSTEMS IN ILLINOIS
Forestry Research Report No. 89-2. Urbana Champaign, USA: University of Illinois, Agricultural Experiment Station, Department of Forestry
35 pp. EN XN/US
ICRAF acc. no: 11218

In part one of this paper agroforestry systems designed for Illinois, USA are described. Trees are planted on contour lines with a spacing of 33 x 130 meter on sloping marginal agricultural land. These systems aim to raise overall economic returns while reducing erosion. Management models were developed for different combinations of three timber species, three site indices, three timber growth rates,

five crops and three tillage systems. In part two the economic attractiveness of such systems is evaluated. Data on tree growth and harvest, erosion reduction, and agricultural yields are all derived from other existing models and used as input for the authors' modeled benefits. (Crop yield reduction due to tree competition had to be estimated.) Costs were derived from the literature and key informants; these are reduced due to cost-sharing by the government, and increased by income tax. Cash flow and net present values for the different options are presented. Black walnut appeared better on the better sites with higher growth rates, whereas red oak performed better on the poorer sites and at lower timber growth rates.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: contour planting
TREE/SHRUB SPECIES: *Juglans nigra, Quercus rubra, Quercus alba*
TREE/SHRUB PRODUCT: timber, fuelwood, pulpwood
TREE/SHRUB SERVICE: soil conservation
DATA SOURCE: biological models, estimates, research plot

035
B
CANNELL, M.G.R. (1989)
FOOD CROP POTENTIAL OF TROPICAL TREES
Experimental Agriculture
Vol. 25 pp. 313-326 EN XZ
ICRAF acc. no: 10509

Trees are an important source of food in both the humid and semi-arid tropics. The author provides a thorough literature review of the role of trees as food crops. Trees can yield as much food per hectare as most C-3 annual crops. However, special problems may have to be overcome to ensure regular bearing of fruit and nut trees. The potential for rapid genetic improvement by clonal selection is enormous. Economic factors favouring tree crops for food include reduced labour requirements for land-clearing and weeding; labour patterns for harvest which complement those for annual crops; and cultivars yielding at different periods of the year, thus evening income flow and reducing risk of food scarcity. Key economic constraints to development of tree crops for food are identified: difficulties in penetrating already well established markets in well known foods, particularly where these are subsidized and where yield increases have already been made through research; current market concentration on only a few tropical tree crops; and especially failure to couple genetic improvement and agronomic research with improved marketing, organization, storage and processing.

TYPE OF ANALYSIS: agroforestry sector analysis, economic concepts/methodology
ANALYSIS LEVEL: region, farm
TREE/SHRUB SERVICE: soil conservation, soil-fertility improvement, shade

036
B
CHATTERJEE, N. (1985)
ECONOMIC ASPECTS OF SOCIAL FORESTRY IN INDIA
In Y.S. Rao, N.T. Vergara and G.W. Lovelace (eds) *Community Forestry: Socio-Economic Aspects.* Bangkok: FAO Regional Office for Asia and the Pacific
pp. 67-114 EN XP/IN
ICRAF acc. no: B3210

Economic aspects of social forestry in India are discussed, starting with analysing the present and future national supply and demand situation and features of forestry products. Given the diversity of the country, various social forestry 'models' have been applied throughout the regions: rehabilitation of degraded forests, strip plantations, community forests on village and state-owned lands, farm forests and individual plantations with tree-tenure of state-owned forests. Seven case studies (presented as appendices) show an interesting diversity of economic evaluations used in these social forestry programme, with varying levels of economic detail.

TYPE OF ANALYSIS: agroforestry sector analysis, partial budgeting ex-post, whole-farm budgeting ex-post, cost-benefit analysis ex-post
ANALYSIS LEVEL: country, region, community, farm
TECHNOLOGY: woodlot, contour planting
TREE/SHRUB SPECIES: *Acacia nilotica, Acacia tortilis, Prosopis juliflora, Albizia lebbeck, Casuarina equisetifolia, Dalbergia sissoo*
TREE/SHRUB PRODUCT: fodder, poles, fuelwood
DATA SOURCE: farm survey, case studies, estimates, unspecified

037
A
CHRISTOPHERSEN, K.A.; KARCH, G.E. (1988)
FINANCIAL AND ECONOMIC ANALYSES OF REFORESTATION, SOIL CONSERVATION AND IMPROVED WOODSTOVE ACTIVITIES: VILLAGE REFORESTATION PROJECT
Paper submitted by Energy/ Development International, Washington D.C. to USAID/Mali, Village Reforestation Project. USAID Energy Initiatives for Africa
63 pp. EN XA/ML
ICRAF acc. no: 8417

This study gives an intermediate review of a reforestation and soil conservation project in Mali, mainly to define the optimal technology to promote in the project. However, due to lack of data collection by the project, cost data for the different interventions (i.e. protecting regrowth of *Faidherbia (Acacia) albida*, live fence, woodlots and construction of contour ridges) were obtained from secondary data and key informants. Benefits are either estimated and net returns expressed in net present values (NPVs) or the authors calculate the minimum amount of cash or amount of crop yield the farmer must obtain per manday in order to recover his investment cost. The outcomes of all interventions are tested for different assumptions on labour costs, discount rate, and crop prices. Woodlots for pole

production appear to be most profitable. *F. albida* protection and prosopis live fences are also worthwhile. Contour ridges had negative NPVs because of high labour costs. Detailed economic data of the 'with' and 'without' situations are presented. A modelling framework (AgroForModel), developed by the authors, was used to analyse soil conservation interventions.

ECOZONE: semi-arid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: project, community, farm
TECHNOLOGY: live fence, contour planting, windbreak, trees mixed in annual cropland
TREE/SHRUB SPECIES: *Faidherbia (acacia) albida, Prosopis juliflora, Parkinsonia aculeata*
TREE/SHRUB PRODUCT: poles, fruit, fuelwood
TREE/SHRUB SERVICE: soil conservation, soil-fertility improvement, fencing, wind protection
CROP/GRASS: millet, sorghum
DATA SOURCE: estimates

038
B
CRACA, L.R.; MENDES, J.B. (1986)
ECONOMIC ANALYSIS OF REFORESTATION SYSTEMS WITH BRACATINGA (*MIMOSA SCABRELLA, BENTH.*); A STUDY ON STATISTICAL DESIGN AND ECONOMIC EVALUATION OF AGROFORESTRY SYSTEMS (Analise Economica de Sistemas de Reforestamento com Bracatinga (*Mimosa Scabrella, Benth.*); Taller sobre Diseño Estadístico y Evaluación Económica de Sistemas Agroforestal)
pp. 105-118 ES XL/BR

An economic analysis is carried out to evaluate three reforestation systems with bracatinga species. The systems were: 1) regeneration induced by fire, 2) direct sowing, 3) associated plantings with corn and beans. The net present value, benefit-cost ratio and internal rate of return criteria are used for the financial analysis. Regeneration induced by fire and intercropped plantings with maize and beans are recommended mainly in new areas. It is not economical to regenerate bracatinga by seedling planting. Data were from a sample of 12 bracatinga growers located around Curtiba, Parana, Brazil.

TYPE OF ANALYSIS: cost-benefit analysis ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: woodlot, trees mixed in annual cropland
TREE/SHRUB SPECIES: *Mimosa scabrella*
TREE/SHRUB PRODUCT: fuelwood, timber
CROP/GRASS: maize, beans
DATA SOURCE: farm survey

039
A
DAVIS, L.S. (1989)
ANALYSIS OF AGROFORESTRY SYSTEMS; A WORKBOOK OF SUPPLEMENTAL TEACHING MATERIAL
Morrilton, Arkansas, USA: Winrock International
203 pp. EN XZ/XP/SL/CH
ICRAF acc no: 12469

This workbook makes an important contribution to the development of economic analysis of agroforestry systems. It has three purposes. First, it presents a conceptual framework in which to quantify, analyse, and evaluate the dynamic nature of agroforestry systems. Second, it makes linear programming a practical tool for analysing agroforestry systems; it provides a software programme on diskette to move data from a Lotus 1-2-3 spreadsheet to LINDO, a widely used computer programme for linear programming. Third, it illustrates the use of the conceptual framework and analytical techniques in three case examples. As an introductory example a simple model is presented of a hypothetical family farm growing beans or beans intercropped with trees. This is expanded by adding different land types, management prescriptions, environmental impacts, crop storage, nutritional requirements, labour 'export and import', price expectations, modelling of supply and demand curves, and finally by introducing the banking and government sector. Absolute, flow and ratio constraints are used. Some constraints are linked. A number of options for a 'strategy for analysis' are presented. A separate chapter provides information on computers, software and file management for this analysis. Lastly, two examples are provided using empirical data: case studies of Sri Lanka forest-garden development and a south China village development project. The book is in draft form for testing by students and working professionals in training workshops. A final version is expected in 1992.

ECOZONE: humid highlands, sub-humid lowlands
TYPE OF ANALYSIS: linear programming
ANALYSIS LEVEL: farm, project, community
TECHNOLOGY: woodlot, taungya afforestation, trees in homegarden, trees mixed in annual cropland
TREE/SHRUB SPECIES: *Persea americana, Eucalyptus spp, Gliricidia spp, Grevillea spp, Psidium guajava, Mangifera indica, Carica papaya, Pinus spp, Bambusa spp, Cunninghamia lanceolata*
TREE/SHRUB PRODUCT: fruit, timber, fuelwood
TREE/SHRUB SERVICE: soil-fertility improvement, soil erosion control
CROP/GRASS: banana, pepper, coffee, cassava, beans, cereals (unspecified)
DATA SOURCE: farm survey, case studies, estimates

040
A
DE GRAAFF, J.; DEDWIWARSITO, K. (1987)
ECONOMIC IMPACT OF WATERSHED DEVELOPMENT ACTIVITIES-REPORT ON 1986/87 IMPLEMENTATION ACTIVITIES IN THE KONTO RIVER WATERSHED, INDONESIA
Working Paper No. 16. Malang, Indonesia: Konto River Project/ DHV Consulting Engineers
99 pp. EN ID/XP
ICRAF acc. no: B05502

An economic analysis of watershed development activities during the final year of the project in three target villages is given. Average household income and employment before implementation is presented first. Subsequently, costs and benefits for different activities are given, also from the point of view of the farmers who participated in implementation of the activities. These data are used to assess the total extent and costs of the activities and to analyse the impact on future income and employment. One of the activities consist of 'Tumpangsari' (=taungya) reforestation schemes in which mostly landless households are given a woodlot of 0.25 ha, which they initially intercrop. Direct on-farm benefits will not offset the high cost of terracing to farmers; soils are deep so erosion is not noticeable to farmers. An attempt is made to assess the downstream benefits of measures to slow down sedimentation in the downstream reservoir and prolong electricity, irrigation and flood control benefits. On the basis of these analyses, a system was set up to monitor the activities in the next year. It consists of simple forms for each activity on which field staff technical, labour and input data on a weekly/monthly basis.

ECOZONE: humid highlands
TYPE OF ANALYSIS: cost-benefit analysis ex-ante and ex-post
ANALYSIS LEVEL: community, project
TECHNOLOGY: fodder bank, contour planting, trees mixed in annual cropland, taungya afforestation
TREE/SHRUB SPECIES: *Agathis robusta, Acacia decurrens, Acacia auriculiformis, Persea americana, Calliandra spp, Cassia spp, Eucalyptus spp, Gmelina arborea, Flemingia spp, Leucaena leucocephala, Maesopsis spp, Sesbania spp*
TREE/SHRUB PRODUCT: fuelwood, fodder
TREE/SHRUB SERVICE: soil conservation
LIVESTOCK: cattle, sheep, goats
CROP/GRASS: rice, maize, vegetables, *Pennisetum purpureum*
DATA SOURCE: farm survey, case studies

041
A
DE MONTGOLFIER-KOUÉVI, C.; HOUÉROU, LE H.N. (1980)
STUDY ON THE ECONOMIC VIABILITY OF BROWSE PLANTATIONS IN AFRICA
In H.N. Le Houerou (ed) *Browse in Africa.* Addis Ababa: International Livestock Centre for Africa
pp. 449-464 EN XA/MW/TN/SN/SD ICRAF acc. no: B0631

This excellent paper assesses the economic feasibility of planting browse trees and shrubs and evaluate the cost price of animal feed produced under relatively extensive conditions, using a minimum of inputs. The data are from experimental cases from Tunisia, Senegal, Sudan, and Malawi drawn from existing literature. The theoretical options for calculating a shadow price for fodder are explained and these are based on a combination of the amount of forage units (FUs) and digestible protein. For each case a detailed overview is given of the production assumptions, management options, the establishment costs with and without fencing, the internal rate of return (IRR), and the cost price per FU. The latter are compared with the shadow price of the produced fodder. In general it can be said that in Africa a browse plantation with a density of 1000 trees/hectare costs on average US$ 500/ha without fencing. These costs can double with barbed-wire fencing. However, planting thorn hedges prolong the non-productive pre-development period. The IRR is extremely sensitive to variations in investment costs and browse yields especially when these are low. If barbed wire fence is included yields should at least be 1000 FU per ha, which is not anticipated for tropical Africa.

ECOZONE: semi-arid, sub-humid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante and ex-post
ANALYSIS LEVEL: farm, plantation
TECHNOLOGY: fodder bank, trees in pasture, trees mixed in annual cropland
TREE/SHRUB SPECIES: *Atriplex spp, Acacia cyanophylla, Acacia senegal, Faidherbia (acacia) albida, Acacia spp, Prosopis spp, Leucaena leucocephala*
TREE/SHRUB PRODUCT: fodder, fuelwood
DATA SOURCE: estimates, research plot, unspecified

042
B
DENTON, F.H. (1983)
WOOD FOR ENERGY AND RURAL DEVELOPMENT: THE PHILIPPINE EXPERIENCE
232 pp. EN XP/PH
ICRAF acc. no: B3204

The production of wood for energy (also called dendro energy) in the Philippines is reviewed in the light of putting up a wood energy thermal power plant. The book contains many data derived from field experiences and estimates, particularly regarding tree production and the costs of wood energy. One chapter deals with the economics of wood energy, showing land costs, farm development costs, tree

harvesting costs, and tree maintenance costs of woodlots for different sites. Both total financial and economic costs per hectare and per wet ton are computed. Income per personday is presented for different wood yields. Elsewhere in the book some extension issues are elaborated upon.

ECOZONE: sub-humid
TYPE OF ANALYSIS: partial budgeting ex-ante
ANALYSIS LEVEL: country, region
TECHNOLOGY: woodlot
TREE/SHRUB SPECIES: *Leucaena leucocephala*
TREE/SHRUB PRODUCT: fuelwood
DATA SOURCE: farm survey, case studies

043
B
DEWEES, P.A.; CAMPBELL, J.G.; FOLEY, G. (1986)
TREE GROWING BY RURAL PEOPLE
Forestry Paper no. 64. Rome: FAO
130 pp. EN XZ
ICRAF acc. no: B4022

This FAO study was organized to understand the context for rural forestry innovations, to review different strategies which have been undertaken to encourage local tree growing, and to discuss programming, planning and institutional issues which have been dominant features of this experience. One of the nine chapters is devoted to evaluating the scope for farm forestry for the market. Another chapter discusses programme planning and design, including economic and financial analysis. This emphasizes the economic perspective of farmers and possible ways in which this may differ from the project planner or government. The final chapter discusses ways of reducing risk in rural tree growing and providing credit. The book presents much case material from agroforestry projects and existing agroforestry systems, and has an extensive bibliography up to 1985.

TYPE OF ANALYSIS: economic concepts/methodology, agroforestry sector analysis
ANALYSIS LEVEL: farm, plantation, region, project
DATA SOURCE: unspecified

044
A
DEWEES, P.A. (1989)
THE WOODFUEL CRISIS RECONSIDERED: OBSERVATIONS ON THE DYNAMICS OF ABUNDANCE AND SCARCITY
World Development
Vol. 17 No. 8 pp. 1159-1172 EN XZ
ICRAF acc. no: 11225

Many analyses of the 'woodfuel crisis' in developing economies take little account of the significant difference between physical and economic woodfuel scarcities. Even when woodfuels become physically scarce, households have a great deal of latitude in changing consumption patterns and tree management practices. The paper suggests that the impacts of the woodfuel crisis are an outcome of fundamental features of the socioeconomy: labour use, land tenure, and usufruct, the transition from subsistence to market economies and cultural practices. The myopic focus on woodfuel production in many forestry interventions has obscured more fundamental issues related to household resource allocation and factor endowments. The greater economic importance of tree uses such as building materials, fruit and fodder, relative to woodfuels, is illustrated with case material from different parts of the tropics. The author concludes by encouraging projects to carry out more comprehensive design exercises which will identify farmers' priority needs for trees and interventions. Examples given are rapid rural appraisals, participatory programme design, agro-ecosystem analysis, baseline surveys and diagnosis and design studies.

TYPE OF ANALYSIS: agroforestry sector analysis
ANALYSIS LEVEL: community, region, country
TREE/SHRUB PRODUCT: fuelwood, charcoal
DATA SOURCE: estimates, unspecified, farm survey

045
A
DEWEES, P.A. (1987)
GUM ARABIC AND THE POTENTIAL FOR STRENGTHENING TRADITIONAL AGROFORESTRY SYSTEMS IN SUDAN
Energy Sector Management Assistance Program, Activity Completion Report. Washington D.C.: The World Bank
pp. 35-59 EN XA/SD

This document provides a comprehensive overview of the economics of gum arabic-based agroforestry systems in the Sudan. It includes sections on the historical use of *Acacia senegal*, international gum markets and prices, gum arabic production, credit and pricing in Sudan, and the economics of incorporating gum arabic into traditional agricultural production systems. For the latter section, six farm models were prepared (annex 5) to show the long-term financial impact of agroforestry. Four 1-feddan models calculate gross cash returns to land and to labour over a single season from the cultivation of sorghum, millet and groundnuts; and from cultivation of gum arabic over a 20-year cycle. Two additional models show returns to traditional rainfed cultivation, integrating three subsistence crops with and without gum arabic on a 10-feddan farm over an entire crop/fallow cycle. The models indicate that integrated crop-gum arabic production makes sound financial sense to the farmers. The author discusses problems of valuation of inputs and outputs in the local context.

ECOZONE: arid, semi-arid
TYPE OF ANALYSIS: agroforestry sector analysis
ANALYSIS LEVEL: farm, region

TECHNOLOGY: trees mixed in annual cropland, improved tree fallow
TREE/SHRUB SPECIES: *Acacia senegal, Faidherbia (acacia) albida*
TREE/SHRUB PRODUCT: gum arabic, fuelwood, charcoal, fodder
TREE/SHRUB SERVICE: soil conservation, soil fertility improvement
DATA SOURCE: estimates, farm survey

046
A
DEWEES, P.A. (1989)
AN ECONOMIC AND SOCIAL HISTORY OF TREES AND FACTOR PROCESSES IN MURANG'A DISTRICT, KENYA
Unpublished Draft. Oxford, UK: Oxford Forestry Institute
120 pp. EN XA/KE
ICRAF acc. no: 11108

This report provides a comprehensive overview of the historical changes in farmers' use of trees between the mid-1800s and the present in Murang'a District, Kenya. By reviewing changing patterns of land tenure and availability, markets for tree products and labour and capital availability among the Kikuyu of Murang'a, the author attempts to explain the current importance of tree planting in the economic strategies of smallholders. The thesis of the study is that the major incentives for tree-growing stem from poorly functioning factor markets leading farmers to seek an alternate source of capital and labour-extensive income-earning options. Substantial detail and historical documentation are provided regarding all of these factors. Further detail is given on traditional tree cultivation and management, and then the significant changes resulting from boundary planting related to land division, and block planting of black wattle. Part of a larger study on economic incentives for tree-growing, the paper closes with an outline of research methodology being used to collect data, including aerial photography and formal and informal surveys.

ECOZONE: humid, sub-humid highlands
TYPE OF ANALYSIS: agroforestry sector analysis
ANALYSIS LEVEL: farm, region
TECHNOLOGY: woodlot, boundary planting
TREE/SHRUB SPECIES: *Acacia mearnsii, Eucalyptus spp, Cupressus lusitanica, Caesalpinia decapatala, Carissa edulis, Croton macrostachys, Dovyalis caffra, Euphorbia tirucalli, Grevillea robusta, Croton megalocarpus*
TREE/SHRUB PRODUCT: timber, poles, tannin
TREE/SHRUB SERVICE: fencing, shade
DATA SOURCE: farm survey

047
A
DOYLE, C.J.; EVANS, J.; ROSSITER, J. (1986)
AGROFORESTRY: AN ECONOMIC APPRAISAL OF THE BENEFITS OF INTERCROPPING TREES WITH GRASSLAND IN LOWLAND BRITAIN
Agricultural Systems
Vol. 21 pp. 1-32 EN XE/GB
ICRAF acc. no: 6664

This paper presents a mathematical model simulating the effect of intercropping trees with grassland on wood production, grass yields and output of sheep meat. Implications of varying density and planting pattern of the trees on total income over time are analysed. The model includes four sub-models: 1) the ground area covered by the woodland canopy; 2) competition for light; 3) competition for water and nutrients; 4) dry matter production of grass and utilisable timber; and 5) estimation of the economic returns from forestry and livestock farming. Technical coefficients for the model are derived from studies of tree and crop physiology, but lack of existing data causes the estimates to rely heavily on unvalidated assumptions. The economic sub-model estimates net present value of returns from timber and meat, the latter based on potential stocking rate. The model is particularly interesting in providing a dynamic analysis of the relationship between changing climatic conditions and economic returns. The model is most useful in identifying specific areas of research needed to develop reliable technical coefficients for such a dynamic analysis.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Fraxinus excelsior*
TREE/SHRUB PRODUCT: fuelwood, timber
LIVESTOCK: sheep
DATA SOURCE: biological models, estimates, research plot

048
B
DULDULAO, A.C. (1985)
STRENGTHENING THE FORESTRY DEVELOPMENT AND TRAINING CENTRE (FDTC) IN KAPTAI (BANGLADESH): AGROFORESTRY DEVELOPMENT GUIDE
Field Document No.3. Kaptai, Bangladesh: Ministry of Agriculture and Forestry and FAO
74 pp. EN XP/BD
ICRAF acc. no: 8512

The 'Agroforestry Development Guide' gives a brief background of the evolution of agroforestry production systems, definitions, objectives and development procedures. The guide ranges from the selection of species to product marketing. It also shows the profitability of agroforestry by projecting possible incomes from

five model combinations of trees with crops as well as factors that may enhance or limit their success. Appended to the guide is a programme for an agroforestry model for rehabilitating hill tract farmers. A detailed discussion about the agroforestry system and a detailed plan for one of the agroforestry demonstration farms are given, showing yield, cost and benefit data.

ECOZONE: sub-humid
TYPE OF ANALYSIS: partial budgeting ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: trees mixed in annual cropland, trees mixed in perennial cropland

TREE/SHRUB SPECIES: *Carica papaya, Citrus spp, Theobroma cacao, Cocos nucifera, Artocarpus integer, Eucalyptus spp, Albizia procera, Leucaena leucocephala*
TREE/SHRUB PRODUCT: fruit, timber, fuelwood
TREE/SHRUB SERVICE: soil conservation
CROP/GRASS: beans, rice, vegetables, coffee
DATA SOURCE: estimates

048
A
DULDULAO, A.C. (1985)
STRENGTHENING THE FORESTRY DEVELOPMENT AND TRAINING CENTRE (FDTC)IN KAPTAI (BANGLADESH): ECONOMIC ANALYSIS OF THE AGROFORESTRY DEMONSTRATION FARMS
Field Document No.4. Kaptai, Bangladesh: Ministry of Agriculture and Forestry and FAO
101 pp. EN XP/BD
ICRAF acc. no: 8513

This report summarizes economic analysis of three agroforestry demonstration farms in Bangladesh. The findings indicate very high profitability of agroforestry as a production system, for farmers who can reduce the expenses of development to one-third or one-fourth of what the project spent. With a proper combination of crops, planted on relatively fertile land, agroforestry is found to generate a net income, ranging from 24012 to 64453 Thaka per acre per year over a 30-year period. Recommendations are made for future management of the farms and the possible adoption of the agroforestry farming system as a programme for natural resources conservation and for uplifting the socio-economic status of the rural people. Detailed individual analyses of the farms, using three different levels of production and income, are included in the appendices.

ECOZONE: sub-humid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: research plot
TECHNOLOGY: trees mixed in annual cropland, trees mixed in perennial cropland, hedgerow intercropping
TREE/SHRUB SPECIES: *Cocos nucifera, Eucalyptus spp, Pinus spp, Leucaena*

leucocephala, Artocarpus integer, Theobroma cacao, Citrus limon, Carica papaya, Psidium guajava
TREE/SHRUB PRODUCT: fruit, timber, fodder, fuelwood
TREE/SHRUB SERVICE: soil conservation
DATA SOURCE: case studies, farm survey, estimates

050
B
DVORAK, K. (1990)
ON-FARM RESEARCH ON ADOPTION POTENTIAL OF ALLEY CROPPING
Paper presented at the workshop on 'Methods for Participatory On-Farm Research in Agroforestry' Feb 19-23 1990, ICRAF, Nairobi
15 pp. EN XA/NG
ICRAF acc. no: 11189

An approach to on-farm economic research on hedgerow intercropping is described, based on on-going studies at the International Institute of Tropical Agriculture, Nigeria with farmer-managed hedgerow intercropping systems. In the first stage of research cost-route surveys and field measurements were carried out for a small sample of farmers. Although research-resource intensive, these detailed studies were necessary to develop a framework for analysing hedgerow intercropping on-farm, because rapid methods of assessing intrinsically dynamic technologies are not yet available. Administration of a focused, formal single-visit survey to a large sample of farmers with hedgerow intercropping at several locations is the second stage. Intensive data collection with a small sample will continue in order to quantify factors identified as key. Annexes describe methods of field measurement, tree counts, tree biomass and maize yield measurements.

ECOZONE: sub-humid lowlands
TYPE OF ANALYSIS: economic concepts/methodology
ANALYSIS LEVEL: farm
TECHNOLOGY: hedgerow intercropping
TREE/SHRUB SPECIES: *Leucaena leucocephala*
TREE/SHRUB PRODUCT: mulch
TREE/SHRUB SERVICE: soil-fertility improvement
CROP/GRASS: cassava, maize

051
A
DYKSTRA, D. (1984)
MATHEMATICAL PROGRAMMING FOR NATURAL RESOURCE MANAGEMENT
Mcgraw-Hill Book Company
311 pp. EN XZ
ICRAF acc. no: B1906

The purpose of this book is to introduce the concepts and techniques of mathematical programming in the context of natural resource management. As an introductory survey, the book emphasizes those techniques that have proved most useful in the analysis of natural resource management problems (including agroforestry practices), especially the different kinds of linear programming. For each technique the author tries to explain the degree of applicability, the basic ideas, the underlying assumptions and limitations. The book is technique- and theory- oriented, and has been used by the author for university courses.

TYPE OF ANALYSIS: linear programming, economic concepts/methodology

052
B
EARL, D.E. (1975)
FOREST ENERGY AND ECONOMIC DEVELOPMENT
Oxford, UK: Clarendon Press
128 pp. EN UG/MG/NP/CI/IN
ICRAF acc. no: B0974

This book provides an analysis of the role of forests in providing renewable energy and explores the costs and benefits of forest energy supply. In one chapter in particular it looks at different costs like cost of raw material, cutting and preparation, transport and storage. It also contains labour data. Most of the book pertains to economics and management of forest plantations, natural forests and enriched forests, but there is also a discussion of taungya afforestation and other integration of forests with agricultural settlements. An appendix provides a hypothetical analysis of the establishment and production costs of a taungya system in Uganda.

TYPE OF ANALYSIS: economic concepts/methodology
ANALYSIS LEVEL: plantation, region
TECHNOLOGY: taungya afforestation, woodlot
TREE/SHRUB SPECIES: *Eucalyptus spp*
TREE/SHRUB PRODUCT: fuelwood, charcoal
DATA SOURCE: estimates

053
A
EHUI, S.K.; KANG, B.T.; SPENCER, D.S.C. (1990)
ECONOMIC ANALYSIS OF SOIL EROSION EFFECTS IN ALLEY CROPPING, NO TILL AND BUSH FALLOW SYSTEMS IN SOUTH WESTERN NIGERIA
Agricultural Systems
Vol. 34 No. 4 pp. 349-368
ICRAF acc. no: 12402

Based on a simulation model, this study uses a capital budgeting (investment appraisal) approach to determine the profitability of alternative land-use systems, taking into account the short and long-run impact of soil erosion on agricultural

productivity in southwestern Nigeria. The fallow systems include: (1) two continuous cultivation hedgerow intercropping systems with leucaena hedgerows planted at 2m and 4m interhedgerow spacings; (2) the continuous cultivation no-till farming system ; and (3) two traditional bush fallow systems with a 3-year cropping period in 6- and 12-year cycles. Maize yields are determined by cumulative soil loss through an equation. Soil loss, in its turn, is predicted through the SCUAF model developed by ICRAF. Under a 10 percent discount rate, when no yield penalties are imposed (reflecting the case of low population density), the 12-year cycle shifting cultivation system is most profitable. It is estimated that annual labour costs must decrease by at least 10 percent for the 4m hedgerow intercropping to be competitive with the 12-year cycle bush fallow system. When penalties are imposed on yields due to land being taken out of production because of fallow vegetation (reflecting the case of rising land values under increasing population pressure), the 4m hedgerow intercropping is most profitable, followed by the no-till. With a discount rate of 35% under high population pressure the no-till system is however more profitable. This is mainly caused by the establishment costs of the hedges. The authors conclude by saying that to test if the technologies fit into the farmers' production plan, economic analysis based on a whole-farm modeling approach is necessary.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: research plot, farm
TECHNOLOGY: hedgerow intercropping
TREE/SHRUB SPECIES: *Leucaena leucocephala*
TREE/SHRUB SERVICE: soil conservation
CROP/GRASS: maize
DATA SOURCE: research plot, farm survey, biological models, estimates, unspecified

054
B
ELLENBROEK, W.E.T. (1986)
PLANTINGS AROUND THE TOWN OF DEDOUGOU (BURKINA FASSO) - AN ECONOMIC STUDY OF AN AGROFORESTRY SYSTEM
(Les Plantations Peri-urbaines de Dedougou (Burkina Fasso) - une Étude Économique d'un Système Agroforestier)
Unpublished draft. Wageningen, The Netherlands: Wageningen Agricultural University
94 pp. FR XA/BF
ICRAF acc. no: 12093

This documents contains a study on financial and economic aspects of four tree plantations in villages around the town of Dedougou, Burkina Fasso, 3-4 years after establishment. These taungya woodlots are managed and intercropped in the first year by the forest service. Local villagers intercrop during year 2 and 3. Main purpose is to provide fuelwood and timber/poles for the town dwellers. Establishment costs are calculated and mainly consist of labour and seedling costs. Average costs of intercropping by the Forest Service are higher than the benefits,

due to low crop yields. Inputs and outputs of intercropping by villagers are presented, showing highly variable yields, depending on cultivating practices, and inversely proportional with tree growth. Costs of fertilizer distribution to villages and tree harvesting costs (in year 7 and 14) are calculated. Future tree yields are estimated for eucalyptus only. Assuming a number of preconditions which could possibly be met, the internal rate of return is 24%. This seems likely for at least 3 of the 4 plantations.

ECOZONE: semi-arid lowlands
TYPE OF ANALYSIS: cost-benefit analysis ex-ante and ex-post
ANALYSIS LEVEL: plantation
TECHNOLOGY: taungya afforestation
TREE/SHRUB SPECIES: *Eucalyptus camaldulensis, Gmelina arborea, Azadirachta indica*
TREE/SHRUB PRODUCT: timber, poles, fuelwood
CROP/GRASS: sorghum, groundnut
DATA SOURCE: case studies, estimates, farm survey

055
A
ELLENBROEK, W.E.T. (1988)
CHARACTERISTICS OF WOOD-SELLING FARMERS IN THE GUNUNG KIDUL DISTRICT (CENTRAL JAVA, INDONESIA)
Unpublished MSc thesis. Wageningen, The Netherlands: Wageningen Agricultural University
73 pp. EN XP/ID
ICRAF acc. no: 12092

The author tries to identify characteristics of farmers who supply the market with wood in Gunung Kidul District, Java, Indonesia. For this purpose determinants of the farmers' wood-selling probability are analysed through logit transformed regression analysis. A model was developed with possible determinants like farm-gate prices, land labour and wood resources, and income generating activities. The analysis shows, however, that the only valid determinants are those for regional variation (mainly nearness of a state-owned forest), wood-demanding home industry, and off-farm employment. The latter two have negative parameters. The price factor is of little influence, and it is therefore expected that price measures will not have much influence. More is expected from forestry extension services, or renting out part of the forest land for forestry schemes. It is also concluded that wood selling from own farm resources is only a minor activity within the upland farming system. The document provides a detailed and clear explanation of the research area, data collection methods as well as analysis through the regression model.

ECOZONE: sub-humid, humid lowlands
TYPE OF ANALYSIS: regression analysis
ANALYSIS LEVEL: region
TREE/SHRUB PRODUCT: fuelwood, charcoal, timber
DATA SOURCE: farm survey

056
B
ENABOR, E.E. (1974)
SOCIO-ECONOMIC ASPECTS OF TAUNGYA IN RELATION TO TRADITIONAL SHIFTING CULTIVATION IN TROPICAL DEVELOPING COUNTRIES
Soils Bulletin no. 24. Rome: FAO
pp. 191-202 EN XA/NG
ICRAF acc. no: 3201

Taungya is proposed as a viable replacement for traditional shifting cultivation in the sub-humid zones of Nigeria. This requires that efforts be made to increase the size of the farm to permit planting of permanent crops, improve the quality of the soil, stimulate adoption of better methods and techniques of cultivation, and to ensure good prices for farmers' products. Diversification of crops is also advocated. The literature research is mainly qualitative.

ECOZONE: sub-humid lowlands
TYPE OF ANALYSIS: economic concepts/methodology, agroforestry sector analysis
ANALYSIS LEVEL: farm, community
TECHNOLOGY: taungya afforestation
TREE/SHRUB SPECIES: *Tectona grandis*
TREE/SHRUB PRODUCT: timber
DATA SOURCE: estimates

057
A
ESTRADA, R.D.; SERÉ, C.; LUZURIAGA, H. (1988)
SYSTEMS OF AGRISILVOPASTORAL PRODUCTION IN THE LOWER SELVA OF NAPO PROVINCE, ECUADOR
(Sistemas de Producción Agrosilvopastoriles en la Selva Baja de la Provincia del Napo, Ecuador)
Cali, Colombia: Centro Internacional de Agricultura Tropical
108 pp. ES XL/EC
ICRAF acc. no: 9303

The study characterizes the production systems prevalent in the Francisco de Orellana district, Napo Province, in northeast Ecuador. It documents the distribution of resources, productivity in pastures, crops and tree crops, and incomes of small farms on three types of soil. It is found that tree densities were below those considered as optimal for agroforestry systems. The inclusion of marketable trees in coffee plots (the main crop) appears to be an attractive alternative because of their low labour requirements and potential value. The main constraints to intensifying production systems in this humid tropical region are specified. Lines of research in agroforestry systems are suggested, together with actions for development needed for the settler-producers in Ecuador's Lower Selva.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: cost-benefit analysis ex-post
ANALYSIS LEVEL: region, farm
TECHNOLOGY: trees in pasture, trees mixed in annual cropland, trees mixed in perennial cropland
TREE/SHRUB SPECIES: *Cordia alliodora, Jacaranda copaia, Cedrela odorata*
TREE/SHRUB PRODUCT: fuelwood, timber
LIVESTOCK: cattle
CROP/GRASS: coffee, maize, plantain, cassava, *Pennisetum purpureum, Brachiaria decumbens*
DATA SOURCE: farm survey

058
A
ETHERINGTON, D.M.; KARUNANAYAKE, K. (1981)
AN ECONOMIC ANALYSIS OF SOME OPTIONS FOR INTERCROPPING UNDER COCONUTS IN SRI LANKA
Unpublished draft. Canberra: Australian National University
28 pp. EN XP/LK
ICRAF acc. no: 2894

Several intercropping options to improve productivity of now mostly monocropped coconut plots of small farmers in Sri Lanka are economically analysed with MULBUD, a computer programme for multi-year budgeting. Size of the plots is assumed to be two hectares with two adult labourers present. Labour is assumed to be available only after paddy and vegetable cultivation. Mature stands of coconuts are given a 'purchase value' in year 1, being the opportunity cost of the land. Three sets of models are presented for years 1-12: 1) a new stand of mature coconuts at standard spacing of 260 trees per ha with no intercropping after year 5, the current 'ruling'; 2) a reduced density of 120 trees per hectare with intercropping up to year 12; 3) growth of intercrops under an existing stand of mature coconuts at standard spacing. Several crops are included and the average annual labour requirements, annuity at 12%, net present value, returns per personday, relative stability of returns to fluctuations in input costs, yields and commodity prices around the 'best guess' estimates are presented. With full intercropping, savings in labour are assumed to be substantial and included in the models. Pepper and banana are the most profitable options with pineapples as a 'second best'.

ECOZONE: humid lowlands highlands
TYPE OF ANALYSIS: cost-benefit analysis ex-ante, partial budgeting ex-ante
ANALYSIS LEVEL: region
TECHNOLOGY: trees mixed in perennial cropland
TREE/SHRUB SPECIES: *Cocos nucifera, Theobroma cacao*
TREE/SHRUB PRODUCT: nuts
CROP/GRASS: pepper, coffee, banana, pineapple
DATA SOURCE: estimates, farm survey

059
B
ETHERINGTON, D.M.; MATTHEWS, P.J. (1982)
ECONOMICS FOR AGROFORESTRY
In E. Zulberti (ed) *Professional Education in Agroforestry; Proceedings of an International Workshop.*
Nairobi: ICRAF
pp. 113-121 EN XZ
ICRAF acc. no: 11226

The authors express the need for economists to play a greater role in decision making in agroforestry. In agroforestry there is often a complementary relationship between crop and tree. However, economists are usually more interested in the competing range of the production possibility curve with two crops/trees. This has often resulted in advocacy of complete specialization in one crop depending on relative prices. Since most tree crop research institutes in the tropics have specialized in one tree, little need was felt for the special skills of an economist, i.e. choice making between competing alternatives. Only institutes involved with small farmers had an economics division. Agroforestry, however, requires choices to be made between spatial arrangement and relationships change over time as well as assessments of risk and uncertainty. MULBUD, a software package for economic analysis of agroforestry, is introduced.

TYPE OF ANALYSIS: economic concepts/methodology
ANALYSIS LEVEL: farm

060
A
ETHERINGTON, D.M.; MATTHEWS, P.J. (1983)
APPROACHES TO THE ECONOMIC EVALUATION OF AGROFORESTRY FARMING SYSTEMS
Agroforestry Systems
Vol. 1 pp. 347-366 EN XZ
ICRAF acc. no: 6061

The economics of agroforestry systems can be approached in a purely analytical fashion with mathematical equations and diagrams explaining the principles of analysis. This paper argues that such an approach may be useful for teaching purposes, but has little practical relevance. There is an urgent need for a practical tool with which multi-disciplinary teams can assess agroforestry systems. The simplest and most common approaches to economic analysis of farm management problems are various forms of budgeting. Recent advances in micro-computer technology provide the means by which the principles of partial budgeting can be adapted to the needs of agroforestry taking account of its multi-component nature, seasonal variability and long life span. The paper sets out the specifications for such an approach, using MULBUD, and indicates how it might be used for intercropping coconut plantings with banana.

TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: trees mixed in perennial cropland
TREE/SHRUB SPECIES: *Cocos nucifera*
Crop: banana
DATA SOURCE: unspecified

061
A
ETHERINGTON, D.M.; MATTHEWS, P.J. (1984)
MULBUD USER'S MANUAL
Canberra: Australia National University, National Centre for Development Studies in Cooperation with ICRAF and the International Development Research Centre
115 pp. EN XZ
ICRAF acc. no: 12446

MULBUD is a user-friendly interactive computer package designed to assist in the economic appraisal of land-use systems involving trees. Trees can be entered as 'sole' enterprises or in combination with other enterprises. The package handles MULtiple-enterprises, multiple products, multiple time periods and provides farm BUDgets of such systems. This is in contrast to single-year partial budgets of systems at maturity being used in the past. This manual explains version 3 but software updates up to version 5 are available now. It provides clear guidelines for data entry, data display and analysis, editing of the data sets, and steps for building multiple enterprise/ whole farm budgets. Examples for all these procedures are given in the form of an analysis of a banana/ ginger plot in Sri Lanka. The production of the 'summary results' table with the labour and material input, gross revenue, net revenue, net revenue per working day, and net present values is shown. Sensitivity analysis is carried out by producing a matrix with varying costs and revenues along the axes. Also a series 'What if..?' bids can be made so as to assess the impact of a range of assumptions.

TYPE OF ANALYSIS: computer program, cost-benefit analysis ex-ante, cost-benefit analysis ex-post,
ANALYSIS LEVEL: farm
DATA SOURCE: unspecified

061
B
ETHERINGTON, D.M.; NAINGGOLAN, S. (1987)
COMBINING STATIC LINEAR PROGRAMMING AND DYNAMIC BUDGETING: A PRACTICAL APPROACH TO IMPROVED LONG TERM PLANNING
Oxford Agrarian Studies vol 16. Oxford, UK: University of Oxford, Agricultural Economics Unit
pp. 23-44 EN XP/ID
ICRAF acc. no: 9849

This paper demonstrates a method of combining static linear programming (LP) and dynamic budgeting (MULBUD) to analyse farm plans involving both long-lived perennials and annual crops. An example is taken from a land settlement scheme in Indonesia, in which commercial rubber and coconut plantation are to be established, with and without intercropping of food crops in immature tree plantations. The multi-step procedure for farm planning includes 1) static optimal farm plan at maturity through LP; 2) LP analysis of static optimal farm plan at immaturity, and 3) multi-period budgeting analysis covering the 30-year planning horizon. The case study analysis highlights the importance of intercropping rubber land with food crops during the establishment phase.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: linear programming, cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: trees mixed in annual cropland
TREE/SHRUB SPECIES: *Hevea brasiliensis, Cocos nucifera*
TREE/SHRUB PRODUCT: latex, nuts
CROP/GRASS: sweet potato, tobacco, rice, soybean, cassava, pepper
DATA SOURCE: unspecified, estimates

063
B
FAIRCLOTH, V.L. (1976)
COSTS AND RETURNS FOR BEEF CATTLE ENTERPRISES ON SOUTHERN PINE TIMBERLANDS
Unpublished MSc thesis. Blacksburg, Virginia, USA: Virginia Polytechnic Institute
152 pp. EN XN/US
ICRAF acc. no: 1753

An economic analysis is carried out on cattle investments on timberland in loblolly-bluestem and slash-wire grass ecosystems of the southeastern United States. Costs and returns for timber and forage production are determined. A computer program is written to simulate investments for a wide range of biological and market conditions and management recommendations. Investments are presented in budget format with investment life equal to the timber rotation. Internal rate of return, present net worth, equivalent annual value and benefit-cost ratios are calculated. Investment returns are very sensitive to timber site index, calving management, beef price, feed supplement expense, pasture fertilization expense, and time cattle are introduced. All data and analyses are presented in tables and appendices.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Pinus elliottii, Pinus palustris, Pinus taeda, Pinus echinata*
TREE/SHRUB PRODUCT: timber

LIVESTOCK: cattle
DATA SOURCE: unspecified

064
B
FALCONER, J. (1990)
AGROFORESTRY AND HOUSEHOLD FOOD SECURITY
In R.T. Prinley (ed) *Agroforestry for Sustainable Production: Economic Implications.*
London: Commonwealth Science Council
pp. 215-239 EN XZ
ICRAF acc. no: B06240

'Household food security' encompasses all factors affecting a household's access to an adequate year-round supply of food. In many areas, forest fallow and farm trees play an important role in household food security, through both productive and protective functions. The main links between agroforestry and food security are reviewed: food, habitat for other foods (mushrooms, lizards), services to crops (soil fertility, windbreak, erosion control), fodder, fuelwood, raw materials for sale and processing, and medicines. Intermediate effects on food security include savings on women's time, cash income, food selection, and environmental conditions (water quality, disease vector control, housing materials). The author stresses the value of trees in mediating seasonal stresses on food supply and other risks. She also focuses on ways in which farmers choose to incorporate trees into the household production system as resource availability (land, labour, capital) changes.

TYPE OF ANALYSIS: economic concepts/methodology, agroforestry sector analysis
ANALYSIS LEVEL: farm
DATA SOURCE: unspecified

065
B
FAO (1979)
PHILIPPINE SMALLHOLDER TREE-FARMING PROJECT
In: *Economic Analysis of Forestry Projects: Case Studies.* Forestry Paper No. 17.
Rome: FAO
19 pp. EN XP/PH
ICRAF acc. no: B0217

This case-study records and financially analyses a forestry project in the Philippines designed to involve and benefit a segment of the rural poor. The Paper Industries Corporation of the Philippines (PICOP) bagan to obtain significant supplies of groundwood from smallholders growing albizia falcataria on farms in the 1960s. Loans are provided to farmers to develop pulpwood plantations to 80% of the farm (typically 8 hectares). The study illustrates institutional arrangements, technical provisions facilitating involvement of the poor, and smallholder incentives. Details are provided on establishing economic

values for project inputs and outputs and the use of sensitivity analysis to explore the implications of uncertainty about these values. No analysis of the effect on the whole farm budget is provided.

ECOZONE: humid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante, economic concepts/methodology
ANALYSIS LEVEL: farm, project
TECHNOLOGY: woodlot
TREE/SHRUB SPECIES: *Albizia falcataria*
TREE/SHRUB PRODUCT: timber
DATA SOURCE: unspecified

066
B
FAO (1981)
INDIA AND SRI LANKA: AGROFORESTRY.
Rome: FAO/SIDA Forestry for Local Community Development Programme
116 pp. EN XP/IN/LK
ICRAF acc. no: 2983

A detailed summary of agroforestry systems in India and Sri Lanka is presented in this report. Areas under shifting cultivation, taungya and other agri-silvicultural mixtures in both countries are provided as well as physical and monetary input/output data. The paper also provides some information and analysis on recently started social forestry and tree farming activities. The study shows many tables and figures based on farmer surveys and detailed case studies. It is concluded that agroforestry for community development can only have lasting effects if there is a change in attitude as well as organizational structure at the Forest Department

TYPE OF ANALYSIS: whole-farm budgeting ex-post, cost-benefit analysis ex-post
ANALYSIS LEVEL: farm, region
TECHNOLOGY: trees mixed in annual cropland, taungya afforestation, woodlot
TREE/SHRUB SPECIES: *Eucalyptus spp, Populus deltoides, Tectona grandis, Leucaena leucocephala*
TREE/SHRUB PRODUCT: fuelwood, timber, fodder
CROP/GRASS: rice, maize, wheat
DATA SOURCE: estimates, farm survey, case studies

067
B
FAO; USAID (1987)
APPLICATION OF ECONOMIC AND FINANCIAL ANALYSIS IN THE PLANNING OF FORESTRY PROJECTS IN THE SAHEL - FINAL REPORT (Application de l'analyse Économique et Financière dans la Planification de Projets Forestiers au Sahel - Rapport Final)
Abidjan: USAID, Energy Initiatives for Africa and Energy Development International
65 pp. FR XA/NE/ML/BF/SN
ICRAF acc. no: 9859

This report summarizes discussions and national studies on financial and economic analyses of agroforestry projects from a seminar held in Abidjan, Ivory Coast (April 1987). It describes the institutional framework and techniques required for the planning of forestry projects. Some global guidelines are presented concerning the costs and benefits est imates of forestry projects, forest protection and forest plantations. Annex 6 contains a brief explanation of a computer model (a Lotus 1-2-3 variant), which can be useful to analyse wood supply and demand data, during the planning of forestry and agroforestry projects.

ECOZONE: semi-arid
TYPE OF ANALYSIS: agroforestry sector analysis, economic concepts/methodology, computer program
ANALYSIS LEVEL: country
TECHNOLOGY: woodlot
DATA SOURCE: unspecified

068
B
FERGUSON, I.S. (1988)
AGRO-FORESTRY AS AN ECONOMIC VENTURE IN AUSTRALIA
Proceedings of the International Forestry Conference for the Australian Bicentenary. Albury, Wodongu, Australia: Australian Forest Development Institute
Vol. 2 11 pp. EN XP/AU
ICRAF acc. no: 9843

The author provides an excellent overview of agroforestry systems being used in Australia and the economic incentives encouraging their adoption. He reviews current practices in pastoral production areas, extensive cropping, intensive cropping, and arid-zone grazing. Economic benefits from agroforestry in the pastoral production areas have been important and documented, whereas there is little information from the other areas. The major preferences of commercial growers currently tend to be towards markets for first thinnings, to avoid a long waiting period for income. Existing data on financial returns from woodlots, shelterbelts, and trees mixed in pastures are reviewed for exotic softwoods, eucalypts and some other species. The author emphasizes the importance of evaluating agroforestry systems as part of whole-farm planning, rather than looking

at the enterprise alone. He identifies the need to evaluate agroforestry in the context of land protection, and the need to develop more efficient paddock design, stock management, and fencing.

ECOZONE: lowlands
TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-ante
ANALYSIS LEVEL: country, farm
TECHNOLOGY: trees in pasture, windbreak, woodlot
TREE/SHRUB SPECIES: *Acacia melanoxylon, Araucaria cunninghamii, Pinus elliottii, Pinus caribaea, Eucalyptus spp*
TREE/SHRUB PRODUCT: timber, fuelwood
TREE/SHRUB SERVICE: soil-fertility improvement, shade, wind protection
DATA SOURCE: unspecified

069
A
FILIUS, A.M. (1988)
ECONOMIC ASPECTS OF AGROFORESTRY
In K.F. Wiersum (ed) *Viewpoints on Agroforestry, 2nd edition.*
Wageningen, The Netherlands: Wageningen Agricultural University
pp. 169-188 EN XZ
ICRAF acc. no: 10491

After an elaboration on the definitions of agroforestry the author explains possible tree-crop relationships in agroforestry. These can be complementary, supplementary, or competitive, which is illustrated with a production possibility curve and practical examples from the literature. The optimum combination will depend on the price ratio of forestry and agricultural products, but this also depends on policy goals. This is illustrated by studies of the implications for farmers of different tree spacing and rotation length in taungya in Java and Tanzania. To assess full consequences of an agroforestry system, a farm level study for complete budgeting is required. The author also explains the effect agroforestry can have on use of labour, land and capital resources. Possible contributions of agroforestry to objectives like 1) improve economic efficiency; 2) improve conditions of the poor; 3) improve environmental conditions; and 4) land use are presented. The paper includes a table with labour requirements, cash expenditure, and income from forest management, agriculture, as well as agroforestry practices in a number of countries.

TYPE OF ANALYSIS: economic concepts/methodology, agroforestry sector analysis
ANALYSIS LEVEL: farm, region, project
DATA SOURCE: unspecified

070
A
FLORES, A.S.; VERGARA, N.T. (1986)
EMPLOYMENT STABILIZATION, LABOUR ABSORPTION AND INCOME POTENTIALS OF AGROFORESTRY AS A MODE OF PRODUCTION: CASE STUDY OF PAPUA NEW GUINEA
Unpublished draft
30 pp. EN XP/PG
ICRAF acc. no: 9853

This study is conducted to assess the socio-economic advantages of various integral agroforestry (AF) systems, involving commercial horticultural tree crops and annual food crops, compared to monoculture tree crops or monoculture annual crops. Data are gathered from 30 farmers representing the highlands, lowlands and coastal regions of Papua New Guinea. It is found that labour employment is more evenly spread over the year in the AF system, and that seasonal fluctuations in labour requirements and income are reduced by 60%. This is caused by the complementarity of labour use in the annual and perennial components of the AF system. Labour absorption has increased 52% in AF. The returns per farm, per capita, per ha and per manday are shown. The first two increase substantially in the AF system. However, returns per ha or per manday of work are not always higher. According to the author this might be due to a marginal value of these resources which is lower than the average revenue and that by using more of these resources profits are higher but returns to these resources lower. Possibly, farmers might also strive for a particular income target only. In the analysis, only a one year-period with full bearing trees is considered.

ECOZONE: humid lowlands highlands
TYPE OF ANALYSIS: whole-farm budgeting ex-post
ANALYSIS LEVEL: farm, country
TECHNOLOGY: trees mixed in annual cropland, trees mixed in perennial cropland
TREE/SHRUB SPECIES: *Cocos nucifera, Hevea brasiliensis, Theobroma cacao*
TREE/SHRUB PRODUCT: fruit, nuts
DATA SOURCE: farm survey

071
B
FORESTRY RESEARCH INSTITUTE, NEW ZEALAND (1989)
THE FRI RADIATA PINE MODELLING SYSTEM - STANDPAK
Unpublished draft
20 pp. EN XP/NZ
ICRAF acc. no: 11223

This paper describes two key components of the Radiata Pine Modelling System developed at New Zealand's Forestry Research Institute. These models are derived from extensive field data and have been widely tested, unlike most existing agroforestry models. The Stand Evaluation Package (STANDPAK) can be used by forest managers or agriculturalists for evaluating alternative management options.

The Forest Estate Modelling System (IFS/FOLPI) may be used for forest management planning. STANDPAK is a predictive tool, simulating growth, harvesting, and processing on a stand or per hectare basis. Modules (consisting of multiple programmes) include early and later growth, log cutting, log quality and grading, harvest and transport, sawlog evaluation, agroforestry, and economic evaluation.

ECOZONE: temperate
TYPE OF ANALYSIS: computer program, cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm, plantation
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Pinus radiata*
TREE/SHRUB PRODUCT: timber
DATA SOURCE: biological models, farm survey, estimates

072
A
GARRETT, H.E.; KURTZ, W.B.; ALIG, R.; HUPE, S.; JONES, J.; RUTLEDGE, G. (1983)
WALNUT MULTICROPPING MANAGEMENT - ITS BIOLOGY AND ECONOMICS
Unpublished draft. Columbia, USA: University of Missouri
pp. 201-212 EN XN/US
ICRAF acc. no: 3338

Four black walnut intercropping systems are examined in this paper. The most complex system consists of planting walnut at wide spacing (12.2x12.2 meters) and intercropping with soybeans and winter wheat for the first ten years, followed by five years of fescue hay and seed production and ultimately grazing. The least complex system consists of providing protection for planted walnut seedlings and grazing throughout the rotation. Based on different economic analysis, black walnut intercropping is found to be an economically viable land-use alternative. The highest returns are associated with the more intensive agricultural management regimes.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: research plot
TECHNOLOGY: trees in pasture, trees mixed in perennial cropland
TREE/SHRUB SPECIES: *Juglans nigra*
TREE/SHRUB PRODUCT: nuts, timber
LIVESTOCK: cattle
CROP/GRASS: soybean, wheat, fescue
DATA SOURCE: research plot

073
B
GARRETT, H.E.; KURTZ, W.B. (1983)

SILVICULTURAL AND ECONOMIC RELATIONSHIPS OF INTEGRATED FORESTRY FARMING WITH BLACK WALNUT
Agroforestry Systems
Vol. 1 pp. 245-256 EN XN/US
ICRAF acc. no: 8766

Four multicropping management regimes for black walnut are studied, including soybeans, fescue, wheat and grass. Nine different management options for each were evaluated. Conditions represent those found in Missouri in the Central United States. Two land quality categories are included. Values for crop yields, tree growth rate, management inputs, etc are estimated from existing biological and economic research data. The financial acceptability of each option is examined using a modified financial analysis algorithm. Internal rate of return (IRR) and present net worth (PNW) are calculated. The analysis shows a clear relationship between financial return and degree of management intensity. The selection of thinning option and rotation length has little influence on financial performance. Financial returns are higher on higher land quality sites. The authors conclude that black walnut intercropping is an economically viable land use alternative.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: trees mixed in annual cropland, trees in pasture
TREE/SHRUB SPECIES: *Juglans nigra*
TREE/SHRUB PRODUCT: timber, nuts
CROP/GRASS: soybean, fescue, wheat
DATA SOURCE: research plot

074
A
GISZ, P.L.; SAR, N.L. (1980)
ECONOMIC EVALUATION OF AN AGROFORESTRY PROJECT
Miscellaneous Bulletin No: 33. New South Wales, Australia: New South Wales Department of Agriculture, Division of Marketing and Economics
19 pp. EN XP/AU
ICRAF acc. no: 4277

The potential role of forestry within a farm in Australia is discussed. The paper presents a case study of a silvipastoral system of improved pasture for sheep between wide-spaced rows of pine trees, grown for timber. From the detailed cost/benefit analyses, the authors conclude that the silvipastoral model gives a better result than the existing sheep-grazing enterprise. In comparison with the other practice, the authors assume a higher discount rate for the silvipastoral model than the existing sheep grazing enterprise, because of the higher risk involved. The study shows yield, cost and benefit data.

ECOZONE: semi-arid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante and ex-post
ANALYSIS LEVEL: project, farm
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Pinus radiata*
TREE/SHRUB PRODUCT: timber
LIVESTOCK: sheep
DATA SOURCE: estimates, unspecified, case studies

075
A
GISZ, P.L. (1982)
AGROFORESTRY: A CASE STUDY ECONOMIC EVALUATION, SOUTHERN TABLELANDS OF NEW SOUTH WALES
Paper presented at the third annual conference of the Australian Forest Development Institute, 19-23 April 1982, Mount Gambier, Australia
10 pp. EN XP/AU
ICRAF acc. no: 4352

This study examines a silvipastoral project near Tarago in New South Wales, Australia. An earlier study (Gisz and Sar, 1980) already showed the project to be economically viable. In this paper some changes in key parameter values have been made in light of experience and knowledge gained since the previous evaluation, i.e. projected pine yields and prices, management costs and capital expense. The agroforestry technology has become less attractive during the time passed between the two studies. The paper presents yield, cost and benefit data.

ECOZONE: semi-arid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: project, farm
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Pinus radiata*
TREE/SHRUB PRODUCT: timber
LIVESTOCK: sheep
DATA SOURCE: case studies, estimates, unspecified

076
B
GLAESER, B. (1984)
ECO-DEVELOPMENT IN TANZANIA: AN EMPIRICAL CONTRIBUTION ON NEEDS, SELF-SUFFICIENCY AND ENVIRONMENTALLY-SOUND AGRICULTURE ON PEASANT FARMS
Berlin/New York/Amsterdam: Mouton Publishers
230 pp. EN XA/TZ
ICRAF acc. no: B4783

This book presents a case study of agricultural needs, practices and potentials in the Shashui area of the Western Usambara mountains of Tanzania. The author used survey tools to construct crop and farm budgets as monocrops and intercrops on 'peasant' and 'professional' managed farms and elicit farmer judgement on different options for increasing yields with traditional methods. Alternatives are then explored, including introduction of wine grapes, macadamia and cardamom as cash crops, appropriate mechanization, and ecological techniques. The latter include trees for fruit, shade and wood planted in contour hedgerows in crop fields. These are evaluated economically using data from experimental fields, but only cost data were available. The study is limited to a more general evaluation of eco-development theory and policy.

ECOZONE: humid highlands
TYPE OF ANALYSIS: partial budgeting ex-ante and ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: trees mixed in annual cropland, trees mixed in perennial cropland, contour planting
TREE/SHRUB SPECIES: *Grevillea robusta, Albizia spp, Persea americana, Cajanus cajan*
TREE/SHRUB PRODUCT: fodder, fuelwood, timber, fruit
TREE/SHRUB SERVICE: shade, soil conservation
CROP/GRASS: potato, maize, beans, sweet potato, cassava, coffee
DATA SOURCE: farm survey, research plot

077
B
GLOVER, N. (1981)
COFFEE YIELDS IN A PLANTATION OF *COFFEA ARABICA VAR. CATURRA* SHADED BY *ERYTHRINA POEPPIGIANA* WITH AND WITHOUT *CORDIA ALLIODORA*
Informe Technico No. 17. Turrialba, Costa Rica: CATIE
25 pp. EN XL/CR
ICRAF acc. no: 3336

In order to quantify the effect of *Cordia alliodora* on coffee yields, a study was initiated in a plantation of arabica coffee, shaded by *Erythrina poeppigiana* with and without cordia. During the 2-year study period coffee yields of individual bushes were measured. First-year results showed a 47% higher coffee yield in the association with cordia. However, second-year yields were 22% lower with cordia. Considering the annual volume increment of cordia, estimated potential gross income was higher from the association with cordia. No labour data are presented.

ECOZONE: humid
TYPE OF ANALYSIS: cost-benefit analysis ex-post
ANALYSIS LEVEL: plantation
TECHNOLOGY: trees mixed in perennial cropland
TREE/SHRUB SPECIES: *Cordia alliodora, Erythrina poeppigiana*
TREE/SHRUB PRODUCT: timber
TREE/SHRUB SERVICE: shade

CROP/GRASS: coffee (arabica)
DATA SOURCE: case studies, research plot

078
A
GOSWAMI, P.C. (1982)
INTEGRATED DEVELOPMENT PLAN FOR SIX WATERSHEDS N.E. OF KINGSTON: FORESTRY PASTURE AND AGROFORESTRY COMPONENTS
Kingston: Government of Jamaica and UNDP/FAO
48 pp. EN XL/JM
ICRAF acc. no: 5001

A development plan is presented for six watersheds in Jamaica covering nearly 90,000 acres. Current land use is summarized, highlighting the importance of farmers' food forests and of agroforestry on public land. Proposals for farm land are to expand and upgrade existing food forests; convert some food forest land to spice-tree forests with mahogany; establish leucaena silvipasture, leucaena woodlots, cocoa and coffee plantations with shade trees and avocado orchards. For public land the recommendation is block plantations of hibiscus and fire protection in protected forests with over 40 degrees slope. Details of labour, inputs, yields and costs for each of the proposals are presented in appendices. A summary of total project costs is also presented.

ECOZONE: humid
TYPE OF ANALYSIS: partial budgeting ex-ante
ANALYSIS LEVEL: farm, plantation, project, region
TECHNOLOGY: woodlot, trees mixed in perennial cropland, tree in pasture
TREE/SHRUB SPECIES: *Leucaena leucocephala, Cola acuminata, Samanea saman, Cajanus cajan, Hibiscus elatus, Persea americana, Theobroma cacao*
TREE/SHRUB PRODUCT: timber, poles, fuelwood, charcoal, nuts, fruit
TREE/SHRUB SERVICE: shade, soil conservation
CROP/GRASS: coffee (arabica)
DATA SOURCE: unspecified, estimates

079
B
GREGERSEN, H.M.; BROOKS, K.N.; DIXON, J.A.; HAMILTON, L.S. (1987)
GUIDELINES FOR ECONOMIC APPRAISAL OF WATERSHED MANAGEMENT PROJECTS
FAO Conservation Guide No. 16. Rome: FAO
144 pp. EN XZ
ICRAF acc. no: B4649

In this paper the authors discuss an economic appraisal of integrated watershed management projects, including agroforestry interventions. It provides guidelines for identification and valuation of a wide range of costs and benefits. The latter emphasizes water availability and soil stabilization. The methods discussed assume a high level of knowledge about underlying technical relationships which will

commonly be unavailable for agroforestry interventions. Chapters include a framework for economic appraisal, estimating input-output relations, quantifying water yield, quantifying benefits of soil stabilization practices, valuing inputs and outputs, comparing benefits and costs, uncertainty, aspects of economic analysis in project design and an economic appraisal itself.

TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-ante
ANALYSIS LEVEL: region
TREE/SHRUB SERVICE: soil conservation

080
B
GRINNELL, H.R. (1977)
A STUDY OF AGRI-SILVICULTURE POTENTIAL IN WEST AFRICA
Ottawa, Canada: International Development Research Centre
52 pp. EN XA
ICRAF acc. no: 1506

This paper reports on a project which tries to identify research priorities to realize the potentials of agrisilviculture. It suggests an effective research programme for development of food crops/ forest tree production systems and an effective machinery for interdisciplinary research in agrisilviculture. An attempt is made to analyse the ecological and social factors behind current farming practices in the humid tropics, and to postulate the benefits that might accrue to the system by establishing forest plantations on the land in the fallow interval. Three research priorities are identified: economics from the farmer's perspective, social and cultural acceptability and efficiency of planted trees in soil improvement compared to natural fallows. A brief review is made of economic data available on these systems, and a model of crop yields and returns is presented to illustrate potentials of planted fallow compared with shifting cultivation. Issues in analysing farm labour constraints are explored.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: economic concepts/methodology, whole-farm budgeting ex-ante
ANALYSIS LEVEL: region, farm
TECHNOLOGY: improved tree fallow, taungya afforestation, trees mixed in annual cropland
TREE/SHRUB SPECIES: *Gmelina arborea, Elaeis guineensis*
TREE/SHRUB PRODUCT: oil, timber, fuelwood
CROP/GRASS: yam, maize, cassava
DATA SOURCE: estimates, unspecified

081
A
GROSENICK, G. (1986)
ECONOMIC EVALUATION OF THE AGROFORESTRY OUTREACH PROJECT
Working Paper No. 6. University of Maine/ Agroforestry Outreach Project (financed by USAID)
62 pp. EN XL/HT
ICRAF acc. no: 7381

The Agroforestry Outreach Project in Haiti is said to have assisted 73,000 farmers. In chapter one the author uses existing survey data of 1% of the farmers (collected four years after the start of the project) for an answer to the question: in what circumstances can the Haitian peasant cash crop trees? This is not clearly answered due to some general assumptions which do not have an empirical basis. Input-output data for crops are derived from existing crop budgets. A standard density of 14.4 square meter per tree is used. Only in the first two years the tree are assumed to be intercropped. Yields on land without trees are assumed to decrease by 2% annually due to erosion. The net present value (NPV) for several tree/crop combinations is calculated for different regions. 15% of the farmers have a negative NPV. This might be partly due to high assumed opportunity costs for land and labour (wage rate for the latter). In chapter 2 the author explores the economics of large-scale tree farms. Chapter 3 presents an analysis of the cumulative benefits of all the millions of trees planted and the financial and economic feasibility of the Project. In chapter 4 some benefits not previously considered like crop diversification, ecological benefits etc. are briefly discussed.

TYPE OF ANALYSIS: cost-benefit analysis ex-ante and ex-post
ANALYSIS LEVEL: project, farm
TECHNOLOGY: woodlot, trees mixed in annual cropland
TREE/SHRUB SPECIES: *Leucaena leucocephala*
TREE/SHRUB PRODUCT: poles, charcoal, timber
CROP/GRASS: cassava, potato, sorghum, beans, groundnut, yam
DATA SOURCE: farm survey, estimates, unspecified

082
B
GUERRERO, S.; LINK, J.; BURNISKE, G. (1987)
MEASURES FOR IMPROVING LOCAL PRACTICES IN AGRICULTURE (MILPA) PROJECT PHASE 1 -PROJECT PROPOSAL-
96 pp. EN XL/BZ

The project proposal of the MILPA-project in Belize contains an agroforestry component. A timber species and a fast growing legume will be planted at 2x2 meter spacing, mixed with beans and corn. A table of expected costs for nursery stock, planting, weeding, thinning, felling and extraction, and the revenues of the sale of logs are presented. It indicates a positive revenue from the proposed system. However many social, technical and institutional constraints at implementation of the project have yet to be solved.

ECOZONE: humid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: project
TECHNOLOGY: trees mixed in annual cropland
TREE/SHRUB SPECIES: *Gmelina arborea, Calophyllum brasiliense, Calliandra spp*
TREE/SHRUB PRODUCT: poles, timber, mulch, fuelwood, fodder
CROP/GRASS: beans, maize

083
B
GUMBO, D.J.; MUKAMURI, B.B.; MUZONDO, M.I.; SCOONES, I.C. (1990).
INDIGENOUS AND EXOTIC FRUIT TREES: WHY DO PEOPLE WANT TO GROW THEM?
In R.T. Prinsley (ed) *Agroforestry for Sustainable Production: Economic Implications*. London: Commonwealth Science Council
pp. 185-214 EN XA/ZW
ICRAF acc. no: 11593

The authors report on village-level research from the 'community management of woodland' project, run by ENDA Zimbabwe in four areas of southern Zimbabwe. The first years of project experience showed that between a quarter and a third of all trees planted were fruit trees, both indigenous and exotic. The reasons for local enthusiasm for fruit trees are explained by historical factors, marketing and transport, local preferences, seasonal roles and economic value. Fruit trees were already important in the project area, mainly indigenous species, left selectively and protected after clearing in cropland or grazing land, and exotic fruits planted in homesteads. Indigenous and exotic trees were found to be complementary, in terms of labour requirements, national availability, and uses. Indigenous trees tended to have a wider range of uses. Markets for fruits are explored, as well as effects of transport on farmer returns. A case example of the farm level economics of an indigenous fruit tree, *Sclerocarya birrea* (mupfura) is presented, showing its use in making beer, commercial sale of nuts, medicinal value, and manufacture of stools and drums. Relative returns to these different uses are analysed. ENDA-Zimbabwe is using the results of this research to help guide project tree-planting priorities.

ECOZONE: semi-arid
TYPE OF ANALYSIS: agroforestry sector analysis
ANALYSIS LEVEL: farm, community
TECHNOLOGY: trees mixed in annual cropland, trees in pasture, woodlot, trees in homegarden
TREE/SHRUB SPECIES: *Sclerocarya birrea*
TREE/SHRUB PRODUCT: fruit, nuts, medecin
TREE/SHRUB SERVICE: soil-fertility improvement
DATA SOURCE: farm survey, estimates

084
B
GUPTA, T.; SAMBRANI, S. (1978)
FARMING SYSTEMS IN HILL AREAS; CONTROL OF SHIFTING CULTIVATION: THE NEED FOR AN INTEGRATIVE APPROACH AND SYSTEMATIC APPRAISAL
Indian Journal of Agricultural Economics
Vol. 33 No. 4 8 pp. EN XP/IN
ICRAF acc. no: 1695

Some operational criteria which must be met by alternatives to shifting cultivation are developed: greater per capita income, the program paying for itself on maturity, land productivity at least as high as under shifting cultivation, internal rate of return greater than social rate of return, labour returns at least as high as before. Terracing and planting of rubber, coffee and cardamon do not seem to meet such criteria. Bamboo plantations appear to have a better potential.

ECOZONE: sub-humid highlands
TYPE OF ANALYSIS: economic concepts/methodology, whole-farm budgeting ex-ante,
ANALYSIS LEVEL: region
TECHNOLOGY: woodlot, improved tree fallow
TREE/SHRUB SPECIES: *Bambusa spp*
DATA SOURCE: estimates, case studies, unspecified

085
B
GUPTA, T.; MOHAN, D. (1982)
ECONOMICS OF TREES VERSUS ANNUAL CROPS ON MARGINAL AGRICULTURAL LANDS
Indian Institute of Management, Ahmedabad. New Delhi/ Bombay/ Calcutta: Oxford & IBH Publishing Company
85 pp. EN XP/IN
ICRAF acc. no: B0655

According to the authors, substantial areas presently under cropping in the hot arid zone of Rajasthan, India are in fact unsuitable for rainfed seasonal cropping. Silvipastoral use of large-scale tree plantations has been identified as an alternative to annual crops. Costs and returns from these two activities are compared. Livestock activities have been excluded, although substantial in the area. It is concluded that individual operators, as well as society as a whole, stand to gain by a shift to tree crops. However, the need for financial subsidies to farmers in the first years is acknowledged. Detailed annual input-output data for six tree species are presented. Data on annual cropping are derived from a survey, but the economics of tree-raising are based on data from research plots.

ECOZONE: semi-arid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: community, research plot
TECHNOLOGY: woodlot
TREE/SHRUB SPECIES: *Acacia tortilis, Albizia lebbeck, Prosopis spp, Ziziphus spp, Leucaena leucocephala*
TREE/SHRUB PRODUCT: timber, fuelwood, fodder
DATA SOURCE: research plot, farm survey

086
B
GUPTA, T. (1982)
THE ECONOMICS OF TREE CROPS ON MARGINAL AGRICULTURAL LANDS WITH SPECIAL REFERENCE TO THE HOT ARID REGION IN RAJASTHAN, INDIA
International Tree Crops Journal
Vol. 2 pp. 155-194 EN XP/IN
ICRAF acc. no: 4480

The author compares the net annual returns from raising of annual crops and livestock, based on a survey of 70 farm households in 5 villages in 1977-78, with estimated returns from an alternative system. The latter involved the growing of pasture grasses and multipurpose tree crops for the production of fodder, fuelwood and small timber. Taking into account a significant increase of persondays of labour per hectare, the silvipastoral system seems to be economically attractive. Detailed input-output studies are presented for several tree species in the hot arid zones of Rajasthan.

ECOZONE: arid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: region
TECHNOLOGY: trees in pasture, woodlot
TREE/SHRUB SPECIES: *Acacia tortilis, Albizia lebbeck, Prosopis spp, Ziziphus spp*
TREE/SHRUB PRODUCT: fodder, fuelwood, fruit, poles
LIVESTOCK: cattle
DATA SOURCE: farm survey, research plot, estimates

087
A
GUPTA, T. (1985)
ECONOMICS OF SILVI-PASTORAL SYSTEMS IN INDIA
In FAO Conservation Guide No. 10: *Sand Dune Stabilization, Shelterbelts, and Afforestation in Dry Zones*. Rome: FAO
pp. 159-167 EN XP/IN
ICRAF acc. no: 6949

Six tree species are analysed for their suitability in pasture in the arid zones of Bikanar District (India) on the basis of a survey of 70 farm households. The species studied were all spaced at 5x5 meter except zizyphus (6x6m) and prosopis (3x3m). Under the trees three different grass species were raised. A detailed scheme of input requirements in different years is presented. The expected returns from air-dried grasses, lopped materials, small timber, green pods, fruits, dry seed and fuelwood are given. The author concludes that, even without considering intangible benefits, the economics of a silvipastoral use of the land resource seem attractive for policy makers. They should encourage farmers to plant trees in their pasture.

ECOZONE: arid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante and ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Acacia tortilis, Albizia lebbeck, Prosopis cineraria, Ziziphus spp, Leucaena leucocephala*
TREE/SHRUB PRODUCT: fruit, poles, fuelwood, tree seed
LIVESTOCK: cattle
CROP/GRASS: *Cenchrus ciliaris, Cenchrum setiqarus, Lasiurus sindicus*
DATA SOURCE: farm survey, research plot

088
B
HAROU, P.A. (1983)
ECONOMIC PRINCIPLES FOR APPRAISING AGROFORESTRY PROJECTS
Agricultural Administration
Vol. 14 pp. 127-139 EN XZ
ICRAF acc. no: 4440

A brief description of the various types of agroforestry projects and basic economic principles to take into consideration for evaluating these systems is given. The author stresses that there is a greater sensitivity to returns as compared to sole cropping. This could be reflected in a risk analysis which would give a lower coefficient of variation for returns from agroforestry systems as compared to monocropping systems. Some of the recommendations for this type of project appraisal are to focus on the small farm participants, to consider the marginal return of the forestry component and risk diversification, to detail the description of the externalities and consider the cultural environment in which the project is to be implemented. An agrisilvipastoral project in the Sahel is discussed to illustrate this last point. The economic analysis of agroforestry projects should be able to reflect its dual function of food production and lower environmental degradation. It is concluded that research aimed at quantifying the difference in inputs, outputs, risk and externalities of agroforestry systems versus monoculture is critically needed.

TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-ante
ANALYSIS LEVEL: project

089
B
HEGDE, N.G. (1989)
SOCIO-ECONOMIC CRITERIA FOR SELECTION OF TREE SPECIES FOR AGROFORESTRY
Unpublished draft. Pune, India: BAIF Development Research Foundation
14 pp. EN XP/IN
ICRAF acc. no: 11222

The author uses the experience of the BAIF agroforestry project in Maharashtra and Karnataka, India to outline key economic factors which influence farmers' decision-making about agroforestry adoption. His thesis is that extension should not attempt to fully design agroforestry systems for dissemination. Rather, the focus should be on selection of tree species identified by farmers to be economically attractive, and their placement in niches in and around crop fields considered suitable by farmers. He emphasizes the variability between villages and farmers in species preferences, but concludes that trees which proved most popular were those with more secure cash markets (fruits, high-value timber, poles) or those with low risk and little input (e.g. Sesbania sesban). Farmers were willing to grow small numbers of trees with high, but delayed, economic returns.

TYPE OF ANALYSIS: agroforestry sector analysis
ANALYSIS LEVEL: farm
TECHNOLOGY: contour planting
TREE/SHRUB SPECIES: *Acacia nilotica, Azadirachta indica, Melia azedarach, Tectona grandis, Thespesia pupulnea, Dendrocalamus strictus, Sesbania sesban Annona squamosa, Ziziphus mauritania, Eucalyptus spp, Tamarindus indica*
TREE/SHRUB PRODUCT: timber, fruit, poles, fodder
DATA SOURCE: farm survey

090
B
HOARE, P.W.C. (1981)
EXTENSION METHODOLOGY AND VILLAGE WOODLOT DEVELOPMENT
Thai-Australian-World Dank Land Development Project. Chiang Mai, Thailand: Land Development Department and the Australian Development Assistance Bureau
62 pp. EN XP/TH
ICRAF acc. no: 3544

This document includes estimated labour requirements and fertilizer inputs for woodlot development as part of the Thai Australian World Bank Land Development Project in Northern Thailand. The woodlots have trees spaced at 3x3 meter. Estimates were made by the project staff as well as by farmers during farmers' meetings. Data include labour for land preparation, planting, fertilizing with manure, and weeding. The project estimate of total labour requirement was 137 persondays per hectare (ha) for a 100 ha block planting. Farmers' estimates

varied from 212 persondays to 400 persondays per ha. Undiscounted benefits from the woodlot for a 10-year cycle as estimated by farmers are presented.

ECOZONE: sub-humid
TYPE OF ANALYSIS: partial budgeting ex-ante
ANALYSIS LEVEL: community, project
TECHNOLOGY: woodlot
TREE/SHRUB SPECIES: *Acacia auriculiformis*
TREE/SHRUB PRODUCT: fuelwood, timber
TREE/SHRUB SERVICE: soil conservation
DATA SOURCE: estimates

091
A
HOEKSTRA, D.A. (1983)
AN ECONOMIC ANALYSIS OF A SIMULATED ALLEY-CROPPING SYSTEM FOR SEMI-ARID CONDITIONS, USING MICRO-COMPUTERS
Agroforestry Systems
Vol. 1 pp. 335-345 EN XA/KE
ICRAF acc. no: 6081

An ex-ante analysis of hedgerow intercropping under the semi-arid conditions of Machakos District, Kenya is presented. Data are adapted from experiments elsewhere under humid conditions. Trees are spaced at 2x1 meter and are assumed to occupy 50% of the land. First lopping takes place after 18 months and subsequently every six months. Maize yield is estimated to increase by 13.5 kg for every kg nitrogen (N) supplied by the mulch. Bean yield varies and either doubles or remains the same. MULBUD-produced tables show economic analysis illustrating the differences from year 1-10 in labour use and flow of net revenue, material requirements, labour requirement and cost, and a detailed account of all inputs and outputs per hectare. Also the net present values (NPVs) at varying discount rates as well as under varying costs and revenues are presented. The NPV of hedgerow intercropping is superior under all assumptions. Break-even organic N production and conversion rates for N-maize are calculated. NPV per manday and per unit of draught power are calculated and also suggest promising results for hedgerow intercropping.

ECOZONE: semi-arid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: hedgerow intercropping
TREE/SHRUB SPECIES: *Leucaena leucocephala*
TREE/SHRUB PRODUCT: fuelwood, mulch
CROP/GRASS: maize, beans
DATA SOURCE: estimates

092
B
HOEKSTRA, D.A. (1984)
AN EX-ANTE ECONOMIC ANALYSIS OF PROPOSED MIXED AND ZONAL AGROFORESTRY SYSTEMS FOR THE BATU ARANG FOREST RESERVE, MALAYSIA
Working Paper No. 16. Nairobi: ICRAF
16 pp. EN XP/MY
ICRAF acc. no: 6105

An ex-ante cost-benefit analysis was carried out to determine the feasibility of potential agroforestry systems for the Batu Arang Forest Reserve in Malaysia. A pure plantation model, growing 3 species in a short rotation of 15 years, is compared to two identified agroforestry systems: one mixed and one zonal model. In the first model farmers clear 1 hectare of land and plant albizia (3x3 meter), with crops in the first year. In the second year shade-tolerant grasses are sown and from year 3-10 sheep are kept. From years 11-15 only trees are grown. This system is repeated on an annual basis, and thus covers 15 ha at maximum. The zonal model divides each ha in a tree zone (0.5 ha), intercropped in the first year, and an agricultural zone where sheep are kept from year 3-15. In both systems farmers receive a labour wage for work on trees from the Forest Department. Based on estimates and literature, detailed input and output data including labour are presented for both systems. From the point of view of the Forest Department, the mixed system gives the highest returns due to decreased planting and weeding costs. This is offset in the zonal system by increased haulage distance due to a greater area needed to produce a similar amount of trees. For the farmers the results are reasonable, but low during the first 5 years. The labour requirement of the 15 ha model may also exceed the one-man equivalent of farms.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm, plantation
TECHNOLOGY: taungya afforestation, trees in pasture
TREE/SHRUB SPECIES: *Albizia falcataria, Gmelina arborea, Acacia mangium, Erythrina poeppigiana*
TREE/SHRUB PRODUCT: timber, fodder
LIVESTOCK: sheep
CROP/GRASS: beans, vegetables, *Brachiaria miliiformi, Calopogonium caeruleum*
DATA SOURCE: estimates

093
A
HOEKSTRA, D.A. (1985)
ECONOMIC CONCEPTS OF AGROFORESTRY
Working Paper No. 30. Nairobi: ICRAF
12 pp. EN XZ
ICRAF acc. no: 6117

In this paper some of the underlying economic concepts of agroforestry are explained as well as economic methods for analysing agroforestry systems. Agroforestry is only viable when mixing perennials with annuals and/or animals is more profitable then growing them separately. There should be biologically and/or economically advantageous interactions between the individual components of agroforestry systems, either immediately or after some time. Biological interactions can be easily extended to economic interactions when the physical output per land unit is replaced by the physical output per unit of total resource cost. Interactions can be manipulated through a proper choice of components and management practices so that positive ones are maximized and negative ones minimized. The need for discounting future benefits in agroforestry to present day values is mentioned. It is stated that the practice of partial budgeting in economic analysis of agroforestry systems will probably remain popular because, compared to linear programming, it is easier to understand and compute while it requires much less data.

TYPE OF ANALYSIS: economic concepts/methodology

094
A
HOEKSTRA, D.A. (1985)
THE USE OF ECONOMICS IN DIAGNOSIS AND DESIGN OF AGROFORESTRY SYSTEMS
Working Paper No. 29. Nairobi: ICRAF
85 pp. EN XA/KE
ICRAF acc. no: 6116

The paper first deals with the use of economics in the diagnosis of existing land use systems. This encompasses descriptions and analysis of such systems at both macro and micro level. An example from Machakos District, Kenya is given. For the use of economics in the agroforestry design process a step-wise approach is suggested and explained. Subsequently, cost-benefit analysis (CBA) in agroforestry is discussed. This includes methods of valuation of inputs (labour, land, capital) and outputs (fuelwood, tree fodder, mulch, and environmental outputs) and distribution of inputs and outputs. Also choosing the discount rate is discussed. Farmers with an optimistic view of their future production will have a higher discount rate than those with a more pessimistic view. Two examples are given: a CBA of hedgerow intercropping and fuelwood plantings on farms, both in Machakos. Lastly, a non-numerical economic analysis is explained in the form of a tree location matrix, in order to arrive at a rational distribution of tree (functions) over the farm. The paper also contains a checklist for inputs and outputs and input-output relationships for diagnosing farming systems.

ECOZONE: semi-arid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante, economic concepts/methodology
ANALYSIS LEVEL: farm, region
TECHNOLOGY: hedgerow intercropping, woodlot, trees mixed in annual cropland

TREE/SHRUB PRODUCT: fuelwood, fodder, mulch, fruit
TREE/SHRUB SERVICE: wind protection, shade, soil conservation, soil-fertility improvement
DATA SOURCE: estimates

095
A
HOEKSTRA, D.A. (1985)
CHOOSING THE DISCOUNT RATE FOR ANALYZING AGROFORESTRY SYSTEMS/TECHNOLOGIES FROM A PRIVATE ECONOMIC VIEWPOINT
Forestry Ecology and Management
Vol. 10 pp. 177-183 EN XZ
ICRAF acc. no: 6083

In this paper it is argued that the discount rate selected for the analysis of agroforestry systems needs careful consideration, especially when dealing with subsistence-oriented farmers. Adopting the borrowing or savings rate, or investment rate, common in most analyses from the private economic viewpoint, will not do since there are reasons to believe that in many cases the consumption rate of interest will, in fact, be lower. Furthermore, it is argued that farmers who are relatively well fed but face sustainability problems on their farms will have a lower discount rate than farmers who are less well fed but expect an upward trend in their production with their present activities. Applying the same discount rate for all farmers should therefore be avoided if there are clear indications that there are differences in relative wealth and future prospects.

TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm

096
A
HOEKSTRA, D.A. (1987)
GATHERING SOCIO- AND BIO-ECONOMIC INFORMATION FOR AGROFORESTRY PROJECTS
Working Paper No. 50. Nairobi: ICRAF
26 pp. EN XZ
ICRAF acc. no: 7356

General principles and guidelines for information gathering for agroforestry projects are provided. The author states that data collection should mainly be used to influence the (re)design and choice of technologies before and during project implementation. The different types of information required and the availability of written information are distinguished for studies on: energy-woodfuel, fodder pods/leaves, shelter materials, fruits/nuts and condiments, and studies on the service role of trees. The same is done for studies on existing technologies, for obtaining inputs and outputs of new agroforestry technologies, studying prices of inputs and outputs, and on research on adoption of agroforestry technologies.

Methods of data collection for the above mentioned type of studies are explained and issues regarding sampling farm surveys and data processing are given. Two sampling approaches (i.e. probability or non-probability methods) are discussed. Probability sampling prevents sampling bias, but needs a good sampling frame which is usually not available. References are provided for a more detailed coverage of the individual topics.

TYPE OF ANALYSIS: economic concepts/methodology
ANALYSIS LEVEL: project, farm

097
B
HOEKSTRA, D.A. (1987)
ECONOMICS IN AGROFORESTRY, A STATE OF THE ART
In J.W. Beer, H.W. Fassbinder and J. Heuveldop (eds) *Advances in Agroforestry Research. Proceedings of a Seminar, 1-11 Sept 1985.*
Turrialba, Costa Rica: CATIE
pp. 36-49 EN XZ
ICRAF acc. no: 9420

The author discusses general economic aspects underlying agroforestry systems and presents methodologies used to collect and analyse data. Problems with valuation of agroforestry outputs, measurement of risks, and handling long time spans are reviewed. Economic features of the better known agroforestry systems like taungya, shifting cultivation, hedgerow intercropping, home gardens, and plantation crop agroforestry systems are presented. The author concludes that linear programming is not expected to become popular in agroforestry due to the large amount of data needed compared to cost-benefit analysis. For farmers with different perceptions of the future different discount rates have to be used. Most analyses so far have been conducted on an ex-ante basis, leaving doubts about data reliability.

TYPE OF ANALYSIS: economic concepts/methodology
ANALYSIS LEVEL: farm
DATA SOURCE: unspecified

098
B
HOEKSTRA, D.A. (1987)
ECONOMICS OF AGROFORESTRY SYSTEMS IN AFRICA
In J.W. Beer, H.W. Fassbinder and J. Heuveldop (eds) *Advances in Agroforestry Research. Proceedings of a Seminar, 1-11 Sept 1985*
Turrialba, Costa Rica: CATIE
pp. 321-330 EN XA
ICRAF acc. no: 9426

Economic characteristics of the most common agroforestry systems in Africa are described. Particular attention is paid to the economics of traditional taungya and departmental taungya and economics of home gardens/compound farming. Subsequently, the biological potential of existing and introduced systems is given. In Africa savings in labour and capital costs per unit of production will have a bigger impact than the savings in land costs. The potential for agroforestry or other tree-based land use systems are good because there is a great demand for woodfuel, small timber, and tree fodder.

TYPE OF ANALYSIS: economic concepts/methodology
ANALYSIS LEVEL: region
TECHNOLOGY: taungya afforestation, trees in homegarden, trees in pasture, live fence
DATA SOURCE: unspecified, estimates

099
B
HOEKSTRA, D.A. (1987)
ECONOMICS OF AGROFORESTRY SYSTEMS IN ASIA
In J.W. Beer; H.W. Fassbinder; J. Heuveldop (eds) *Advances in Agroforestry Research. Proceedings of a seminar, 1-11 Sept 1985*
Turrialba, Costa Rica: CATIE
pp. 331-336 EN XP
ICRAF acc. no: 9427

A review of economic studies on both traditional and adapted/new agroforestry systems in Asia are represented. These include for the humid zone taungya afforestation in Thailand, home gardens in Indonesia, plantation crop based systems in Malaysia and Sri lanka. For the sub-humid/semi-arid zones silvipastoral systems and woodlots in the Indian subcontinent are presented. It is concluded that the available information usually shows a good economic return for some of the mentioned systems.

TYPE OF ANALYSIS: economic concepts/methodology
ANALYSIS LEVEL: country, farm, plantation
DATA SOURCE: unspecified

100
B
HOEKSTRA, D.A. (1988)
PRELIMINARY RESULTS ON-FARM ALLEY CROPPING TRIALS KAKUYUNI AREA
Research Report No. 6. Republic of Kenya, Dryland Agroforestry Research Project
9 pp. EN XA/KE
ICRAF acc. no: 12475

This brief paper analyses findings of the on-farm hedgerow intercropping trials in the Kakuyuni catchments area, Kenya. After a description of the area and the four selected farmers, the trial plots are introduced. Method of establishment is explained but no labour data were collected. Present spacing varies between 3-4 meters between row and is 0.5 in-row, but actual tree density varies considerably due to poor gapping up. Results of the first lopping exercise after about 320 days are shown. Biomass production varied considerably. Labour input measurements were taken from relatively uniform biomass hedgerows. The weighted (for hedge length) average hedge length cut per hour was 83 meter with a standard deviation (SD) of 52 meter. 98 trees were cut per hour (SD 27 trees) with 88 kg of biomass (SD 41 kg). Subsequently, Pearson correlation coefficients were computed to determine the amount of correlation between the above parameters. The length harvested per hour is inversely correlated to the number of trees per meter. Also there was a very clear correlation between the biomass harvested per hour and the biomass production per tree. No other correlations could be found.

ECOZONE: semi-arid
TYPE OF ANALYSIS: economic concepts/methodology
ANALYSIS LEVEL: farm
TECHNOLOGY: hedgerow intercropping
TREE/SHRUB SPECIES: *Leucaena leucocephala, Cassia siamea, Gliricidia sepium*
DATA SOURCE: case studies

101
A
HOFSTAD, O. (1978)
PRELIMINARY EVALUATION OF THE TAUNGYA-SYSTEM FOR COMBINED WOOD AND FOOD PRODUCTION IN NORTH EASTERN TANZANIA
Record No. 2. Dar es Salaam: University of Dar es Salaam, Faculty of Agriculture, Forestry and Veterinary Science, Division of Forestry
14 pp. EN XA/TZ
ICRAF acc. no: 1224

The taungya system which has been used extensively in Tanzania during the last decades is now on the decline. The author tries to justify continued use of taungya. Five options are economically analysed: 1) wood production only 2) crops and trees planted at the same time with crops during two years 3) crops only for two years then trees and crops with crops during three years 4) crops only for five years then trees and crops with crops during three years and 5) like option 2 but with paid labour. Results show that taungya is more profitable due to the added agricultural production but present values for the Forest Division are lower in option 4 and 5. Some arguments against taungya are discussed and commented on by the author who concludes that taungya is still a good practice from which the Tanzanian society as a whole and the local peasants in particular benefit significantly.

ECOZONE: humid highlands
TYPE OF ANALYSIS: cost-benefit analysis ex-ante

ANALYSIS LEVEL: plantation
TECHNOLOGY: taungya afforestation
TREE/SHRUB SPECIES: *Pinus patula*
TREE/SHRUB PRODUCT: timber
CROP/GRASS: maize, beans
DATA SOURCE: estimates, unspecified

102
A
HOSIER, R.H. (1982)
SOCIAL BENEFIT COST ANALYSIS OF FUELWOOD DEVELOPMENT PROJECTS IN KENYA
Working Paper, Beijer Institute Fuelwood Project. Stockholm: The Beijer Institute
55 pp. EN XA/KE
ICRAF acc. no: 3691

Developing a methodology for the evaluation of fuelwood projects in Kenya is the main purpose of this paper. The more recent works in general as well as energy-oriented project appraisal in developing countries are reviewed. A methodology to be applied on the specific requirements of fuelwood projects is proposed and discussed. Four methods of valuing fuelwood in a project are addressed: 1) valuing the labour saved because of collecting firewood from trees planted by the project; 2) and 3) estimate the paraffin and charcoal equivalent respectively; and 4) the price of wood in the local market. The latter is found to be the most accurate measure. Valuation of parameters like the shadow price of unskilled, skilled labour and of foreign exchange are discussed, as well as the choice of discount rates. For social analysis it is concluded that impact on savings and income distribution would be impossible to calculate. However, fuelwood could be considered as a merit-want good, whose market value is lower than its contribution to national well-being. A correction factor is therefore proposed and specified. The author also applies the above techniques to identify data from Kenya which can be used in fuelwood project appraisal.

TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis
ex-ante (economic)
ANALYSIS LEVEL: project
TREE/SHRUB PRODUCT: fuelwood
DATA SOURCE: farm survey, estimates

103
A
HOSIER, R.H.; GELDER, B. VAN (1982)
THE ECONOMICS OF OPTIMAL FUELWOOD PRODUCTION TECHNIQUES
Working Paper, Beijer Institute Fuelwood Project. Stockholm: The Beijer Institute
20 pp. EN XA/KE
ICRAF acc. no: 3688

The authors discuss the economics of the optimal rotation period for forestry projects. Using a production function it is shown that the maximum sustained gross yield of wood is obtained if a tree is cut at the end of the period of maximum growth, and not at the point of the maximum gross yield. However, the economically optimal rotation period is determined by maximizing the discounted present value. An algebraic function and graphs are used to show that this makes the optimum rotation period even shorter. Subsequently, attention is paid to the production of fuelwood in developing countries. Here, according to the authors, an early yield of small sticks is preferred due to time preference, ease of harvesting and handling. Close planting of trees (1x1 meter or less) is needed to achieve this which also maximizes productivity per hectare. A production curve of this system is presented. Two hypothetical fuelwood production schemes in Kenya are compared as an example: one is a short rotation closely-planted calliandra which is coppiced every year, the other a eucalyptus woodlot only harvested after 10 years and only thinned twice. The cashflow of both systems is presented and the internal rate of return calculated showing a much higher outcome for the calliandra. The authors conclude that 0.25 ha of this system should be enough to provide fuelwood for a whole year for an average household (5.7 cu.m.).

ECOZONE: sub-humid highlands
TYPE OF ANALYSIS: production-function analysis, cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm, plantation
TECHNOLOGY: woodlot
TREE/SHRUB SPECIES: *Calliandra calothyrsus, Eucalyptus spp*
TREE/SHRUB PRODUCT: fuelwood
DATA SOURCE: estimates

104
B
HOSIER, R.H. (1987)
THE ECONOMICS OF AGROFORESTRY: OBSTACLES AND INCENTIVES TO ECODEVELOPMENT
Perspectives in Agroforestry, Technical Report No. 2. Pullman, USA: Washington State University, Agroforestry Consortium
23 pp. EN XA/KE/XL/HT
ICRAF acc. no: 9847

This review of the economics of agroforestry examines the theoretical literature relevant to agroforestry analysis and presents two case studies. The literature review identifies key texts on forestry development economics, agricultural economics, and recent agroforestry economics, as well as a few better known applications. The first case study presents an ex-ante analysis comparing 'fuelstick' versus conventional woodlots in the Kenya Woodfuel Development Project. The second case study describes an ex-post analysis of costs and benefits of a mixed intercropping system for wood production in the Agroforestry Outreach Program of Haiti. The cases are used to identify important analytical problems in economic evaluation. The author concludes by emphasizing the importance of farmer-level cost-benefit analysis in projects, the critical role of labour input analysis,

marketability issues, the impact of national policies, and the role of farmers as final arbiters of the value of an agroforestry practice.

ECOZONE: humid highlands
TYPE OF ANALYSIS: cost-benefit analysis ex-ante and ex-post, economic concepts/methodology
ANALYSIS LEVEL: farm, project
TECHNOLOGY: trees mixed in annual cropland, improved tree fallow, woodlot
TREE/SHRUB SPECIES: *Calliandra calothyrsus, Eucalyptus saligna*
TREE/SHRUB PRODUCT: fuelwood, poles
DATA SOURCE: unspecified, farm survey, estimates

105
A
HOSIER, R.H. (1989)
THE ECONOMICS OF SMALLHOLDER AGROFORESTRY: TWO CASE STUDIES
World Development
Vol. 17 No. 11 pp. 23 EN XA/KE/XL/HT
ICRAF acc. no: 9957

The author starts with a review of the literature on agroforestry (AF) economics and concludes that on-farm cost-benefit analysis (CBA) is the most appropriate analytical tool to measure the overall profitability of any AF system. The farmer needs to be adequately compensated for his labour in order to accept it. Two case studies from the literature are analysed. The first is an ex-ante CBA of the Kenya Woodfuel Cycle Project. Two approaches of afforestation are compared, i.e. conventional Eucalyptus woodlots (2.5x2.5 meter, harvested after 10 years) with a short rotation calliandra (1x1m) plot. The latter appeared to have a higher internal rate of return due to earlier benefits. It was therefore advocated in extension efforts. However, it was overlooked that growing poles for sale in the woodlots solved farmers' cash constraint and was therefore also popular with farmers. The second example is an ex-post CBA of the AF Outreach Programme in Haiti. It showed that 15% of the farmers involved in the project had negative returns. The author attributes this to static assumptions on the cropping pattern leading to a too high opportunity cost of land, lack of information, or the possibility that AF may not be the best solution for these farmers. In general, important issues in CBA of AF are: opportunity cost of land, the discount rate , and the value of labour, which is never zero.

ECOZONE: humid highlands
TYPE OF ANALYSIS: cost-benefit analysis ex-ante and ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: woodlot, trees mixed in annual cropland
TREE/SHRUB SPECIES: *Eucalyptus saligna, Calliandra calothyrsus*
TREE/SHRUB PRODUCT: fuelwood, poles
DATA SOURCE: unspecified, farm survey, estimates

106
B
HOUT, P. VAN DER (1984)
EFFECTS OF WIDER INITIAL SPACING OF TEAK (*TECTONA GRANDIS*) ON INCOME AND INCOME DISTRIBUTION IN THE TAUNGYA SYSTEM IN JAVA
Netherlands Journal of Agricultural Science
Vol. 32 pp. 139-142 EN XP/ID
ICRAF acc. no: 9950

A model was developed with an altered spacing of teak trees (6x1 meter instead of 3x1 meter) in a taungya system in Java, Indonesia. It was postulated that this would enable farmers to prolong the intercropping period from 2 to 4 years. The model considers teak cultivation in an 80-year rotation, intercropped with rice, maize and leucaena. The net present value for the farmer and the forest enterprise were calculated. Whereas the farmer sees his profit increase considerably, the forest enterprise loses almost nothing. Land hunger in the area is relieved and the basic needs of the rural poor are met to a higher degree.

ECOZONE: humid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: plantation
TECHNOLOGY: taungya afforestation
TREE/SHRUB SPECIES: *Tectona grandis, Leucaena leucocephala*
TREE/SHRUB PRODUCT: timber, fuelwood
CROP/GRASS: rice, maize
DATA SOURCE: estimates, unspecified

107
B
HYMAN, E.L. (1983)
LOAN FINANCING OF SMALLHOLDER TREEFARMING IN THE PROVINCES OF ILOCOS NORTE AND ILOCOS SUR, THE PHILIPPINES
Agroforestry Systems
Vol. 1 pp. 225-243 EN XP/PH
ICRAF acc. no: 8750

In 1978 the World Bank financed a scheme to produce fuelwood on 8000 ha of smallholders' fields for the tobacco-curing industry in the Ilocos region, the Philippines. Proposed were intercropped plantings of *Leucaena leucocephala* (spacing 1x2 meter) coppiced in the fourth year, mainly for fuelwood. Three and a half years later a survey carried out by the author showed that production was likely to be only 4-5% of the anticipated quantity because of a low participation rate in the loan scheme, high mortality rates of trees, inadequate forestry extension services, and poor market infrastructure. A cost-benefit analysis was made showing detailed labour and material costs per hectare (270 persondays are needed over four years). The net present values and internal rates of return are given for 24 scenarios resulting from different assumptions for yields, land costs, wage rates, labour shadow pricing and financial or economic prices. It appears that

only with low land costs (i.e. on sites which are sub-marginal for agriculture) the project is worthwhile. The outcome is quite sensitive to the pricing of labour.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: cost-benefit analysis ex-ante and ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: woodlot, trees mixed in annual cropland
TREE/SHRUB SPECIES: *Leucaena leucocephala*
TREE/SHRUB PRODUCT: fuelwood, fodder
CROP/GRASS: rice, cassava, pineapple, vegetables, sweet potato
DATA SOURCE: estimates, unspecified

108
A
HYMAN, E.L. (1983)
PULPWOOD TREE FARMING IN THE PHILIPPINES FROM THE VIEWPOINT OF THE SMALLHOLDER: AN EX-POST EVALUATION OF THE PICOP PROJECT
Agricultural Administration
Vol. 14 pp. 23-49 EN XP/PH
ICRAF acc. no: 8119

An ex-post evaluation is made of the World Bank-financed smallholder tree-growing project for pulpwood delivery to the Paper Industries Corporation of the Philippines. The project succeeded in recruiting a large number of participants due to 1) expectations of good economic returns with low labour input 2) the provision of good technical extension services and 3) the guarantee of a market for the output. Farmers grew albizia trees in an 8-year cycle on a plot with a minumum size of 5 ha (spacing 4x4 meter). Instead of the scheduled staggered planting most areas were planted at once. This resulted in harvest bottlenecks, especially shortage of labour. This put farmers at the mercy of contractors, since loans did not allow for harvest costs. Only 7% of the farmers interplanted their woodlots. For 24 scenarios based on different assumptions, the discounted costs and benefits of the system are calculated. Although a typhoon damaged trees, this was not included in the analysis, and only scheduled yields were used. Data are all from a single-visit survey carried out by the author, but some data are based on estimates.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: cost-benefit analysis ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: woodlot
TREE/SHRUB SPECIES: *Albizia falcataria*
TREE/SHRUB PRODUCT: pulpwood
DATA SOURCE: farm survey, estimates

109
B
JACKMAN J.B.; KNOWLES, R.L. (1973)
INTEGRATED FARMING AND FORESTRY: PROFITABILITY ANALYSIS
Paper presented to the Interdepartmental Meeting 25-26 Sept 1973, Rotorua, New Zealand
17 pp. EN XP/NZ
ICRAF acc. no: 11621

This paper has been prepared to identify factors having a major influence on the profitability of integrating timber trees and grazing land in New Zealand. Analysis is carried out from three perspectives: an individual diversifying a grazing enterprise with trees, a forest company purchasing farmland for tree-planting, and the Forest Service purchasing farmland for the same purpose. Using a range of current production and price data from forestry and farming, a comparison of alternatives is made for individuals, distinguishing large and small farms. Cash flow analysis is also undertaken. Sensitivity analyses are carried out for: site index, distance from port/road, rotation length, pasture production, forestry yields, land initially in scrub, and forestry costs. Implications for research and development include: 1) small changes in grazing are less significant than small changes in forestry 2) intercropping is more favourable on larger farms 3) more forestry cost data are needed 4) site index has a major effect on forestry returns and 5) the cash flow gives no problem if a woodlot is less than 10% of the farm area.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante, whole-farm budgeting ex-ante
ANALYSIS LEVEL: plantation, farm
TECHNOLOGY: woodlot, trees in pasture
TREE/SHRUB SPECIES: *Pinus radiata*
TREE/SHRUB PRODUCT: timber
LIVESTOCK: sheep, cattle
DATA SOURCE: estimates

110
B
JACOB, V.J.; ALLES, W.S. (1987)
KANDYAN GARDENS OF SRI LANKA
Agroforestry Systems
Vol. 5 pp. 123-137 EN XP/LK
ICRAF acc. no: 7436

This paper examines the potential for increased productivity in the Kandyan homegarden system of Sri Lanka. Data are from a survey of 30 farms, and from mixed cropping experiments. The structure and composition of the system are described and data are presented on resource input and utilization (labour and cash), and production for the 25 most important crops. Proportion sold and consumed on farm are indicated for each crop, and seasonal distribution of income within the year on individual farms was calculated. The scope for system

improvement is illustrated by results from crop combination experiments initiated in 1978. Fourteen different plant species of different architecture were included in carefully designed planting patterns. Annual returns from a one- hectare mixed cropping model is estimated, showing a marked increase in income potential. The authors identify priority research needs as: selection of appropriate compatible species; arrangement and spacing of components according to input and management; use of high-yielding, fast-growing cultivars; response of components and the system to management constraints; input-output relations; and long-term sustainability.

ECOZONE: humid
TYPE OF ANALYSIS: partial budgeting ex-ante and ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: trees in homegarden
TREE/SHRUB SPECIES: *Areca catechu, Artocarpus heterophyllus, Cocos nucifera, Piper nigrum, Syzygium aromaticum, Theobroma cacao*
CROP/GRASS: plantain, coffee, tea
DATA SOURCE: farm survey, research plot

111
B
JIANG, A. (1986)
THE ECOLOGICAL EFFECT AND ECONOMIC RESULT OF A JUJUBE-TREE-BELT-CROP SYSTEM IN NORTH CHINA PLAIN
Paper presented at the International Symposium on Windbreak Technology, 23-27 June 1986, Lincoln, Nebraska, USA
4 pp. EN XP/CN
ICRAF acc. no: 7023

The Jujube-tree is a common perennial fruit tree in the North China Plain. Jujube trees are cultivated in parallel belts in the cereal fields, mostly composed of a single row. The author argues that besides many ecological effects, economic results show higher cereal yields and a significant contribution to the cash income of small farmers. The study also presents a mathematical model to identify the optimum combination of jujube tree and annual crops in the field. Only yield and income data are presented; no costs are given.

ECOZONE: temperate
TYPE OF ANALYSIS: partial budgeting ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: windbreak
TREE/SHRUB SPECIES: *Ziziphus jujuba*
TREE/SHRUB PRODUCT: fruit
TREE/SHRUB SERVICE: wind protection
CROP/GRASS: cereals (unspecified)
DATA SOURCE: farm survey

112
B
JODHA, N. (1987)
A CASE STUDY OF THE DEGRADATION OF COMMON PROPERTY RESOURCES IN INDIA
In Blaikie and Brookfield (eds) *Land Degradation and Society.*
London and New York: Methuen
pp. 196-207 EN XP/IN
ICRAF acc. no: 11224

The author presents an historical evaluation of the evolution in use management and quality of rural common property resources in Rajasthan, India. Analysis is based on fieldwork carried out in 1963-65, 1973, 1978, and 1982-84. Innovative methods for assessment were applied. Indicators and factors influencing land degradation are discussed for village forest, and several types of pasture. The changing species composition, density and use of woody perennials in these niches are documented. Several factors are identified as contributing to the changing economic role, scale and productivity of common property (including wood resources): new economic incentives for land management under land reform, changing methods for revenue generation from common property, transformation from pasture to cropping on land distributed to the landless, mechanization of common-property-based activities, and changes in the economics of livestock production.

ECOZONE: semi-arid
TYPE OF ANALYSIS: agroforestry sector analysis
ANALYSIS LEVEL: region
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Ziziphus nummularia*
TREE/SHRUB PRODUCT: fodder, fuelwood
LIVESTOCK: CAMEL, sheep, goats, cattle
DATA SOURCE: farm survey, case studies

113
B
JOSEPH, N.S. (1987)
AN EX-ANTE ECONOMIC APPRAISAL OF MONO-CROPPING, MIXED CROPPING AND INTERCROPPING OF ANNUAL AND PERENNIAL CROPS
Agricultural Systems
No. 24 pp. 67-80 EN XA/CM
ICRAF acc. no: 7205

The paper presents a comparative economic study of monocropping, mixed cropping and intercropping of annual and perennial crops using a discounted cash flow analysis. Data are from a case study of a village settlement project in Cameroon. The project faces problems of high desertion by farmers, low production and low productivity. This results from the practice of mixed cropping. The study demonstrates that intercropping in row arrangements is an important improvement on mixed cropping and that it reasonably meets the objectives of

both the settlers and the project. The results also indicate that apart from the sole cropping of plantains (the most profitable of the seven systems compared), the intercropped systems are more profitable and reliable than the mixed cropped systems. The study shows no cost or benefit data of the different cropping systems. Only the net present values and their sensitivity-tests are presented.

ECOZONE: humid lowlands
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: research plot, farm
TECHNOLOGY: trees mixed in annual cropland
TREE/SHRUB SPECIES: *Theobroma cacao*
CROP/GRASS: plantain, maize, groundnut, cassava, beans, coffee (robusta)
DATA SOURCE: farm survey, estimates, research plot

114
B
KAJOMULO-TIBAIJUKA, A. (1985)
FACTORS INFLUENCING THE CULTIVATION OF FIREWOOD TEES ON PEASANT FARMS: A SURVEY ON SMALLHOLDER BANANA-COFFEE FARMS, KAGERA REGION, TANZANIA
Unpublished draft.
Uppsala, Sweden: Swedish University of Agricultural Sciences, International Rural Development Centre
No. 18 34 pp. EN XA/TZ
ICRAF acc. no: 5799

The author attempts to explain the level and patterns of cultivation of trees by smallholder banana-coffee farmers in the Kagera Region of Tanzania. Based on data collected from 200 family farms in 10 villages, the analysis shows that population increases coupled with declining food crop yields due to pests and soil fertility decline have halted the traditional practices of interplanting trees on banana plantations. Some households have substitute woodlots on grasslands to address fuelwood shortages. Detailed data are presented on agroforestry species and practices, as well as income/expenditure data on fuelwood and kerosene, and income data from sale of timber trees. The role of trees as cash earning enterprises for some households is considerable, representing 13% of coffee income and 30% of banana income. Analysis is carried out for villages with different population densities.

ECOZONE: humid highlands
TYPE OF ANALYSIS: agroforestry sector analysis
ANALYSIS LEVEL: region, farm
TECHNOLOGY: woodlot, trees mixed in perennial cropland, boundary planting
TREE/SHRUB SPECIES: *Eucalyptus spp, Pinus spp, Bambusa spp*
TREE/SHRUB PRODUCT: fuelwood
CROP/GRASS: coffee, banana
DATA SOURCE: farm survey

115
B
KALLA, J.C.; CHAND, G.; VYAS, D.L. (1975)
ECONOMICS OF COMMERCIAL FUEL PLANTATION CROPS IN ARID ZONE OF RAJAHSTHAN
Agricultural Situation in India
Vol. 30 No. 4 pp. 241-244 EN XP/IN
ICRAF acc. no: 759

Four popular tree species which have been found suitable for commercial production of fuel on degenerated land in arid areas were analysed. Cost and benefit data per hectare are presented for the period 1963-74, collected from the silvicultural experiments conducted at research farms. The present worth of investment results for all three species in positive net returns, with highest returns for the acacia (93%) followed by albizia (21%) and prosopis (20%). Data on costs and benefits are presented including labour and yield.

ECOZONE: arid
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: research plot
TECHNOLOGY: woodlot
TREE/SHRUB SPECIES: *Albizia lebbeck, Azadirachta indica, Prosopis juliflora, Acacia tortilis*
TREE/SHRUB PRODUCT: fuelwood
DATA SOURCE: research plot

116
B
KASS, D.L.; BARRANTES, A.; BERMUDEZ, W.; CAMPOS, W.; JIMINEZ, M.; SANCHEZ, J. (1989)
RESULTS OF SIX YEARS OF HEDGEROW INTERCROPPING RESEARCH IN 'LA MONTAÑA', TURRIALBA, COSTA RICA
(Resultados de Seis años de Investigación de Cultivo en Callejones en 'La Montaña', Turrialba, Costa Rica)
El Chasqui Vol. 19. Turrialba, Costa Rica: CATIE
pp. 5-24 ES XL/CR
ICRAF acc. no: 04507

This paper reports the results of 6 years of hedgerow intercropping research by CATIE in Costa Rica. Seven treatments were evaluated: a control, mulch of erythrina, cattle manure, mulch of gmelina, intercropping of vigna later replaced by gliricidia mulch, hedgerow intercropping with erythrina cut back twice a year, and hedgerow intercropping with gliricidia. Some fertilizer treatments were applied. Experimental results offer good evidence of the sustainability and stability of cropping systems based on the use of leguminous trees. Maize yields did not increase significantly, probably due to the already high fertility levels of the soil. Economic analysis based on experimental results was undertaken. This showed the relatively high cost of labour and transport of fresh biomass material, and also the relatively low cost of mineral nitrogen. Nonetheless, the system in which pruned

material was used as the only source of phosphorus and potassium, was most economical and required less capital, despite labour costs. Research on mechanized options for pruning and transport of green manure is suggested. Higher economic returns may come from separating trees and crops, rather than integrating.

ECOZONE: humid
TYPE OF ANALYSIS: partial budgeting ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: hedgerow intercropping
TREE/SHRUB SPECIES: *Erythrina poeppigiana, Gmelina arborea, Gliricidia sepium*
TREE/SHRUB PRODUCT: mulch
TREE/SHRUB SERVICE: soil-fertility improvement
CROP/GRASS: beans, maize, cassava
DATA SOURCE: research plot, estimates

117
B
KELLAS, J.D. (1987)
SYMPOSIUM TAKES A CLOSE LOOK AT AGROFORESTRY
Australian Forest Grower, April 1987
pp. 4-6 EN XP/AU/NZ
ICRAF acc. no: 9861

The Radiata Pine Agroforestry Model (RAM) is being developed by the New Zealand Forest Research Institute, Rotorua. This is a predictive model for tree and pasture growth, through time as an adjunct to the plantation management model, STANDMOD. The plantation model permits simulation of plantation growth, log yield, harvest cost, processing and transport, focusing on a clear wood management regime. RAM includes additional tree components, such as effect of pruning and thinning on tree growth and impact of shading and rate of decay of prunings or pasture production. Agricultural components include livestock carrying capacity and changes due to trees, etc. The model calculated net present value of revenue and costs and internal rate of return. Technical coefficients are based on on-going research at the institute.

ECOZONE: temperate
TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm, research plot
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Pinus radiata*
TREE/SHRUB PRODUCT: timber
TREE/SHRUB SERVICE: shade
LIVESTOCK: cattle, sheep
CROP/GRASS: *Lotus uliginosus*
DATA SOURCE: research plot, biological models

118
B
KNOWLES, R.L.; PERCIVAL, N.S. (1983)
COMBINATIONS OF PINUS RADIATA AND PASTORAL AGRICULTURE ON NEW ZEALAND HILL COUNTRY - II FORESTRY PRODUCTIVITY AND ECONOMICS
In *Foothills for Food and Forests*, Oregon State University Symposium
Vol. 2 pp. 203-218 EN XP/NZ
ICRAF acc. no: 9964

A recently developed simulation model (SILMOD) was used to compare the volumes and net present worth (NPW) of stands of *Pinus radiata* with final tree densities of 100/ha, 200/ha, and 400/ha grown in conjunction with understorey pasture. Various site variables were altered like rotation length, slope, basal area, and distance to the mill, and the effects on NPW. A final tree density of 100/ha was more profitable than the other treatments, although clear timber yields did not vary much. An additional analysis for two levels of agricultural gross margins of livestock grazed under the trees further favoured the lower tree stocking. These preliminary results indicate a considerable level of compatibility between agriculture and forestry on New Zealand hill country. The model, when complete, will allow site- and management-specific evaluation of agroforestry proposals involving *P. radiata* and pastoral agriculture.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: research plot
TECHNOLOGY: trees in pasture
TREE/SHRUB SPECIES: *Pinus radiata*
TREE/SHRUB PRODUCT: timber
LIVESTOCK: sheep
DATA SOURCE: research plot, biological models, estimates

119
A
KOLJONEN, K. (1984)
ADOPTION OF AGROFORESTRY - A DECISION-MAKING PROBLEM OF THE TANZANIAN PEASANTS
Reports and Discussion Paper No. 40. Espoo, Finland: Pellerro Economic Research Institute
45 pp. EN XA/TZ
ICRAF acc. no: 4270

The author discusses decision-making elements and methods for analysing the adoption of the taungya-system by small farmers. It is suggested that small farmers usually take a 'satisfying decision approach' (trial and error method) rather than an optimizing one. Three different case-studies with *Eucalyptus melliodora* (Ngoja, 1981), *Pinus patula* (Hofstad, 1979) and *Leucaena leucocephala* (Mosha, 1982) are described. Cost-benefit analyses show that the agroforestry practice leads to lower profitability than non-agroforestry systems. The main reason is the long rotation

period of trees as compared with crops, leading to reduced benefits of forest output if the time aspect is taken into account by means of discounting.

ECOZONE: humid highlands
TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: taungya afforestation
TREE/SHRUB SPECIES: *Eucalyptus melliodora, Pinus patula, Leucaena leucocephala*
CROP/GRASS: maize, sorghum, beans
DATA SOURCE: estimates, research plot

120
B
KORT, J. (1989)
FBECON.WK1 - A LOTUS 1-2-3 SPREADSHEET FOR CALCULATING SHELTERBELT ECONOMIC BENEFITS
Paper presented at Prairie Farm Rehabilitation Administration, Soil Conservation Annual Staff Meeting, Regina, Sask, Canada
11 pp. EN XN/CA
ICRAF acc. no: 11581

This paper describes a LOTUS 1-2-3 spreadsheet which has been designed to allow the user to enter various parameters relating to shelterbelt species and design, as well as crops and cropping inputs and returns. The spreadsheet calculates the economic beneficial effects of the shelterbelts on crop yields, taking into account variables such as shelterbelt effectiveness, competitiveness, lifespan and growth rate, as well as differential crop response and the effect of location and orientation of the windbreaks. Different scenarios can be considered. A hypothetical example from Sasketchewan, Canada is used to illustrate the use of the spreadsheet.

ECOZONE: temperate
TYPE OF ANALYSIS: economic concepts/methodology, computer program, cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: windbreak
TREE/SHRUB PRODUCT: timber
TREE/SHRUB SERVICE: wind protection
DATA SOURCE: estimates

121
B
KUCHELMEISTER, G. (1989)
HEDGES FOR RESOURCE-POOR LAND USERS IN DEVELOPING COUNTRIES
Eschborn, Germany: Deutsche Gesellschaft für Technische Zusammenarbeit
256 pp. EN XZ
ICRAF acc. no: B06161

This book provides an overview of the roles hedges can play for the rural poor in developing countries. It is based on 406 literature references and includes a chapter on sociological and economic issues in hedgerow growing (pp.115-132). Increased labour demand caused by hedges can have a negative effect on the small farmer's labour economy. The author also mentions the importance of farmer's attitudes, preferences and knowledge, the role of land tenure, farmer's need for contingencies and other social constraints. Establishment costs of hedges are compared for different establishment methods with labour inputs varying between 150-600 meters per manday. Establishment through seedlings can sometimes be uneconomical. The author states that most 'hard' economic data are from hedgerow intercropping studies. Labour inputs and profitability calculations of hedgerow intercropping are given based on the ex-ante analysis of Hoekstra (1983) and ex-post on-station analysis of Ngambeki (1985). Finally, the extra costs involved in tractor-ploughing between the hedges alley-cropped plots is presented.

TYPE OF ANALYSIS: economic concepts/methodology, cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: hedgerow intercropping, live fence, windbreak
TREE/SHRUB PRODUCT: fuelwood, fodder, mulch
TREE/SHRUB SERVICE: soil conservation, soil-fertility improvement, fencing, wind protection
DATA SOURCE: unspecified

122
B
KUMAR, P.H. (1981)
PROBLEMS AND PROSPECTS OF ESTABLISHING A FORESTRY PLANTATION WITH CASUARINA, CASHEW AND COCONUT IN THE COASTAL BELT OF INDIA
Rivesta di Agricola Subtropicale e Tropicale
Vol. 75 No. 4 pp. 317-323 EN XP/IN
ICRAF acc. no: 3610

A zonal system of *Casuarina equisetifolia*, cashew and coconut is proposed for the reclamation and utilization of sandy lands. A brief economic analysis is presented with unspecified costs; benefits are estimated. It is concluded that the proposed system of casuarina rows between mixed stands of coconut and cashew trees is

highly profitable from the national point of view. Such a system would also function as windbreak against gale and cyclone damage to the agricultural crops in the interior coastal areas. These benefits are, however, not considered in the analysis.

TYPE OF ANALYSIS: partial budgeting ex-ante
ANALYSIS LEVEL: country
TECHNOLOGY: trees mixed in perennial cropland, windbreak
TREE/SHRUB SPECIES: *Anacardium occidentale, Casuarina Equisetifolia, Cocos nucifera*
TREE/SHRUB PRODUCT: fuelwood, timber, nuts
TREE/SHRUB SERVICE: wind protection, soil conservation
DATA SOURCE: estimates

123
A
KURTZ, W.B.; GARRETT, H.E.; KINCAID JR, W.H. (1984)
INVESTMENT ALTERNATIVES FOR BLACK WALNUT PLANTATION MANAGEMENT
Journal of Forestry
Vol. 82 No. 10 pp. 604-608 EN XN/US
ICRAF acc. no: 9854

The authors evaluate investment alternatives for managing black walnut plantations as a sole stand for timber or timber and nuts, as a simple agroforestry mixture including wheat, and as a complex agroforestry system for production of timber, nuts, wheat, soybeans, fescue hay and grazing for cattle. The paper incorporates findings from six years of multi-cropping research in Missouri, although none of the models has been implemented and validated over an entire rotation. It provides a detailed application of economics and farm management to the analysis of mixed cropping systems. Internal rates of return (IRR) and net present worth (NPW) are calculated, and highest returns are indicated for the intensive multi-cropping regimes. Those regimes reduce sensitivity of IRR to final harvest values, but increase risk due to possible damage to trees from machinery and livestock. Greater IRRs are evident for higher quality sites.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: research plot
TECHNOLOGY: trees mixed in annual cropland, trees in pasture
TREE/SHRUB SPECIES: *Juglans nigra*
TREE/SHRUB PRODUCT: timber, nuts
TREE/SHRUB SERVICE: shade
LIVESTOCK: cattle
CROP/GRASS: soybean, wheat, fescue
DATA SOURCE: research plot, farm survey, estimates, biological models

124
B
KURTZ, W.B.; GARRETT, H.E. (1989)
ECONOMIC ASPECTS OF EASTERN BLACK WALNUT MANAGEMENT
Paper presented at the First International Symposium on Walnut Production, 25-29 Sept 1989, Budapest, Hungary
7 pp. EN XN/US
ICRAF acc. no: 11556

This paper presents a financial analysis of an on-going long-term black walnut management project established near Stockton, Missouri in the USA. It illustrates the differences in profitability between various plantation-management options, including agroforestry and conventional cropping systems. Special management options include thinning, removal of prunings, weed control, harvesting equipment, and application of herbicides and fertilizers. Agroforestry allows the grower to spread risk through diversification. Agroforestry management regimes yield greater financial returns than either black walnut grown for timber only or for timber and nuts, or a conventional rotation of soybeans and winter wheat.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante and ex-post
ANALYSIS LEVEL: farm
TECHNOLOGY: trees mixed in annual cropland
TREE/SHRUB SPECIES: *Juglans nigra*
TREE/SHRUB PRODUCT: timber, nuts
CROP/GRASS: soybean, wheat
DATA SOURCE: case studies, research plot

125
B
KURTZ, W.B.; THURMAN, S.E.; MONSON M.J.; GARRETT, H.E. (1989)
THE ECONOMICS OF EROSION CONTROL THROUGH AGROFORESTRY ON NORTH WEST MISSOURI FARMS
Proceedings of the 1989 Farming Systems Research/Extension Symposium, Fayetteville, Arkansas, USA
10 pp. EN XN/US
ICRAF acc. no: 11647

This paper reports on part of a larger research programme to evaluate the biological and economic feasibility of agroforestry for controlling soil erosion on agricultural land. Four agroforestry systems, i.e. American sycamore for biomass production, Scotch pine for christmas trees, and black walnut for timber production or timber and nuts, were evaluated as enterprises in three common crop rotations, on three sizes of farms, in two large relatively homogeneous geographic areas. The objectives of the simulation exercise were to 1) identify agroforestry configurations which would reduce soil erosion to acceptable levels, and 2) evaluate the financial aspects of each agroforestry configuration relative to conventional conservation practices. The study concluded that agroforestry is a low-input alternative to terracing for soil erosion control, and (except for biomass)

is more profitable over the long term than conventional practices. Christmas-tree agroforestry is the most profitable system.

ECOZONE: temperate
TYPE OF ANALYSIS: cost-benefit analysis ex-ante
ANALYSIS LEVEL: farm
TECHNOLOGY: boundary planting, contour planting
TREE/SHRUB SPECIES: *Platanus occidentalis, Pinus sylvestris, Juglans nigra*
TREE/SHRUB PRODUCT: timber, nuts, fuelwood
TREE/SHRUB SERVICE: soil conservation
CROP/GRASS: maize, soybean, wheat
DATA SOURCE: estimates, biological models

126
A
LAGEMANN, J. (1977)
TRADITIONAL AFRICAN FARMING SYSTEMS IN EASTERN NIGERIA
Munich, Germany: Weltforum Verlag
269 pp. EN XA/NG ICRAF acc. no: 2894

Land use in three villages with different population densities in the root crop/oil-palm farming system in eastern Nigeria is compared. The author found that soil fertility declines with higher population density, and that farmers react by concentrating production on small compounds with high input of mulch, manure, and household refuse. Multi-storey homegardens are not found at low population densities (100-200 persons/km square). Labour input per unit area did not differ significantly between the outer fields and the compounds. The average gross returns to labour from compound farming were 4 to 8 times higher than from the outer fields. The labour productivity on compounds is found to diminish with increased population densities. Labour, yield, cost, and benefit data of the homegardens and outer fields are presented.

TYPE OF ANALYSIS: whole-farm budgeting ex-post, cost-benefit analysis ex-post
ANALYSIS LEVEL: community
TECHNOLOGY: trees in homegarden
TREE/SHRUB SPECIES: *Cocos nucifera, Elaeis guineensis*
TREE/SHRUB PRODUCT: fruit, nuts, oil
CROP/GRASS: cassava, yam, maize, cocoyam, vegetables
DATA SOURCE: farm survey

127
A
LAGEMANN, J.; HEUVELDOP, J. (1983)
CHARACTERIZATION AND EVALUATION OF AGROFORESTRY SYSTEMS, THE CASE OF ACOSTA-PURISCAL, COSTA RICA
Agroforestry Systems
Vol. 1 pp. 101-115 EN XL/CR
ICRAF acc. no: 2928

An overview of existing agroforestry systems in Acosta-Puriscal, Costa Rica is given. These include coffee in combination with trees, pasture in combination with trees, and trees in live fences. The paper explains the procedure for evaluating these systems. A comparative evaluation of two agroforestry systems is presented, i.e. coffee with shade trees and coffee with shade trees plus fruit trees, each for two different coffee varieties. This is absed on the preliminary analysis of a multi-visit survey carried out weekly on 68 farms for one production cycle. Labour input, gross margin and net income are given, showing the highest return for the hybrid coffee with shade trees. The conclusion that production from the increased density of trees off-sets the loss of coffee yield is not fully supported by the data.

ECOZONE: humid highlands
TYPE OF ANALYSIS: partial budgeting ex-post, cost-benefit analysis ex-post, economic concepts/methodology
ANALYSIS LEVEL: farm, region
TECHNOLOGY: trees mixed in perennial cropland
TREE/SHRUB SPECIES: *Inga spp, Gliricidia sepium, Erythrina spp, Citrus spp*
TREE/SHRUB PRODUCT: timber, fuelwood
TREE/SHRUB SERVICE: soil-fertility improvement, shade
CROP/GRASS: coffee
DATA SOURCE: case studies

128
B
LAHIRI, A.K. (1972)
INTERCROPPING TRIALS WITH TURMERIC IN NORTH BENGAL
The Indian Forester
Vol. 98 No. 2 pp. 109-115 EN XP/IN
ICRAF acc. no: 9958

Trials with an intercrop of turmeric in teak and sal plantations which were at leat two years old were undertaken in Kurseong Forest Division, North Bengal, India, testing different densities and land preparation techniques. Yield data of the crop show that 20-25 quintals of turmeric can be obtained from a hectare of forest plantation. Both costs and benefits are estimated for the crop-growing activity only. Cost of cultivation is higher in manually worked areas than in mechanized ones, but small but positive net profits for the crop component are received for both. It appears that as a result of the extra attention the trees also did better, as documented by improved growth rates.

ECOZONE: humid
TYPE OF ANALYSIS: partial budgeting ex-ante and ex-post
ANALYSIS LEVEL: research plot
TECHNOLOGY: taungya afforestation
TREE/SHRUB SPECIES: *Shorea robusta, Tectona grandis*
TREE/SHRUB PRODUCT: timber
CROP/GRASS: turmeric
DATA SOURCE: research plot