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April-June, 1984

USAID-ICRAF COOPERATIVE AGREEMEN

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PROJECT NO. 936-5545

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1. INTRODUCTORY NOTES (J.B. Raintree)

This is the seventh report of the USAID-ICRAF Cooperative Agreement, Project No. 936-5545, for the period from April-June, 1984.

According to the three-year agreement which became effective as of 1 September 1982, ICRAF receives support from USAID for three projects of ICRAF's Programme of Work. These are:

- Agroforestry Training
- Diagnostic and Design Methodology Development, and
- Agroforestry Systems Inventory

Progress reports in respect of the three projects for the period, prepared by the respective project leaders, are attached. The second ICRAF/USAID Agroforestry Course was held this quarter in Nairobi and preparations are underway for the 3rd Course to be held in Malaysia in October, 1984. In the D&D project, collaboration was initiated with the International Labour Organization to assist in incorporating D&D aspects into practical training modules for Village Polytechnics in Kenya, and a proposal was developed for collaboration with the SPOT satellite programme to use ground truth information from the Kathama D&D site to evaluate the new high resolution imagery for large scale diagnostic applications. Several new reports on AF Systems Inventory results were submitted for publication during the quarter and progress was made in developing a standard format for computer coding and analysis of the primary data.

The financial statement for the period is included, following the individual progress reports.

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2. AGROFORESTRY TRAINING (E. Zulberti)

2.1 First ICRAF/USAID Agroforestry Course, Kenya, 1-8 Nov. 1983

Follow-up. After a period of in-house discussion (last quarter) a follow-up questionnaire was mailed to course participants on 26 April 1984. The form was specifically designed to provide feedback on to what extent agroforestry information/knowledge/methods are being put into use as a consequence of the participants attending the ICRAF/USAID Course. A copy of the form is presented in Annex 1. Eight questionnaires have, so far, been returned. A report on feedback information gathered by this means is to be prepared later in 1984. A fourth communication was also sent from the Training Unit to all course participants together with a copy of the first booklet of the ICRAF Science and Practice of Agroforestry series (see Annex 2)

2.2 Second ICRAF/USAID AF Course, Kenya, 4-22 June 1984

Pre-Course Activities. An in-house seminar was held at ICRAF on 16 May with the aim to review the general planning and organizational details of the programme. At this time E. Zulberti briefed ICRAF staff on the technical background and professional experience of the selected participants.

The Course was announced in countries/institutions where already exist some kind of collaborative activities or is likely to begin in the near future. The criteria for the selection of sponsored participant remained the same as for the first Course (see Progress Report 4 page 2-4). Seventy-two applications from countries in Africa and Latin America were received and analyzed (see summary of applications in Annex 3). Twenty-five participants attended the June Course representing twelve African countries and two Latin American ones. The names and addresses of participants is presented in Annex 4. A strong interest in ICRAF training and dissemination activities became evident amongst the international community e.g.

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two national institutions from developing countries (Uganda and Malawi) sent representative under own government sponsorship; two international centers (ILCA and the Ford Foundation Sudan) also sent candidates under their support.

Two communications were sent to all participants prior to the Course. An official nomination to attend the Course under the USAID sponsorship sent by the Director and a letter with instructions on finance/administrative matters sent by EZ together with a package of general information about the Course programme and participants, as well as on ICRAF activities and staff members (see Annex 6).

Training Materials. A basic package of general information about ICRAF and Nairobi was handed over to participants on Registration Day (Monday 4 June) together with the first set of the Training Materials required during the first week of the Course. The organization of the Training Package followed approximately the same sequence as the one prepared for the First Course, but the content was selectively screened to include only those articles, documents directly related to the programme presentations. Nonetheless, lists of references were available as well as supplementary materials for those participants with specific technical interests. A set of the Training Package is included in Annex 6.

A Slide Set on "Agroforestry Systems in Developing Countries" was jointly prepared by the Training Unit and the Agroforestry Systems Inventory Project (PKR Nair/E. Fernandez). The set includes twenty slides illustrating a variety of agroforestry systems/practices in and around the tropics, covering the major ecozone types (Humid and Sub-humid; Tropical Highlands; Semi-arid). The slides were accompanied by a six-page document with a short legend on each one. A copy of the set is attached to the Training Package. The Slide Set was sold to participants upon request, at a nominal cost of USD 2.00

The Course Programme. Activities began on 4 June when participants came to ICRAF for registration and general information purposes. At that time they received the Training Package, the general information package and the payment of the first per diem installments.

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Official start was made on Tuesday 5 with a brief opening session by Dr. Peter Huxley, Officer in Charge. In general terms, the scope and content of the Course programme focused on the "Conceptual and Technical Background of Agroforestry" (first week), the "Diagnostic and Design Methodology" (second and half of third week) and "Experimental Designs in Agroforestry" (second half of third week). Copy of the detailed programe of activities is attached to the Training Package.

Training sessions included formal lectures, case studies, workshops, working groups and independent study/work, as well as consultations with ICRAF staff. Field exercises were carried out during the first and second weeks.

ICRAF's multidisciplinary team participated in the training activities covering a wide range of conceptual, methodological and practical topics. On 22 June (last day of the course), after the overall course review and evaluation session, participants received a certificate of attendance followed by a modest farewell gathering at ICRAF.

The overall course programme coordination was run by E. Zulberti with backup support from all ICRAF scientific as well as administrative staff.

Course Monitoring and Evaluation. Monitoring procedures were applied throughout the development of the course with the aim to detect programme difficulties, if any, and apply quick corrective measures on time. E. Zulberti carried out review sessions at the end of the first and second weeks of the course as part of the programme of activities. Some adjustments were made during the third week to adjust to the speed of the groups' work. Largely, the programme of activities and general coordination was followed as originally planned.

An evaluation form was filled by participants and an oral evaluation session was carried out at the end of the Course. In general, participants expressed very positive comments about this three-week Course. A final report with the summary of information gathered and an analysis of the implications for future courses will be presented in early August 1984.

2.3 Third ICRAF/USAID Agroforestry Course

An agreement was reached with the University Pertanian Malaysia (UPM), the Malaysian Agricultural Research Institute (MARDI), the Forestry Research Institute in Malaysia (RRIM) to jointly host the third ICRAF/USAID in October 1984. E. Zulberti undertook a mission to Malaysia during May 20-25 to start the coordination of the course logistics and support from institutions involved. All the above are COSPRO Collaborating institutions. The Course will be held at UPM from 1 to 19 October 1984. Invitations to institutions in the region have already been sent, mainly to India, Indonesia, Thailand, Malaysia and the Philippines (see Annex 7).

Dr. Kamis, Head of the Forestry Department at UPM was designated as the national Course coordinator and is at present closely collaborating with E. Zulberti. A preliminary Timetable for the Malaysia course is presented in Annex 8.

2.4 Fourth ICRAF/USAID Agroforestry Course

As mentioned in the previous Progress Report (January-March 1984), contacts were initiated with COSPRO collaborating institutions in India to jointly organize one of the ICRAF/USAID Courses in 1985. Authorities in India have expressed a positive attitude towards the proposals presented but no final decision has been reached yet.

Alternatively, a similar training proposal was discussed with Mr. Manual Villavicencio, Director of the Experimental Station in Yurimaguas, Peru and also a COSPRO collaborating institution. An enthusiastic response from Mr. Villavicencio leads us to think that it would be feasible to organize the fourth Agroforestry Course in the series next June 1985 at the Agroforestry Project site in Yurimaguas. However, further developments are expected to take place soon as Dr. Torres is at the present time in a COSPRO mission in Peru. Mr. Villavicencio attended the ICRAF/USAID Course in Kenya 4-22 June 1984.

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3. DIAGNOSIS AND DESIGN PROJECT (J.B. Raintree)

3.1 Dissemination of the Methodology

Requests continue to come in from all over the world for copies of the two draft D&D manuals (Working Papers 6 and 7, copies appended to an earlier quarterly report). To date, the entire first run of 300 copies of *Guidelines for Agroforestry Diagnosis and Design* have been distributed and approximately 180 copies of *Resources for Agroforestry Diagnosis and Design.* A new run of 200 copies of the *Guidelines* has been produced to meet the continuing demand.

During the quarter the following invited paper was produced and submitted to the organizers of the indicated meeting:

J.B. Raintree. A systems approach to agroforestry diagnosis and design: ICRAF's experience with an interdisciplinary methodology. VI World Congress for Rural Sociology, Working Session No. 26: Interdisciplinary Collaboration in Rural Development--Dream or Reality? 15-21 December, 1984. Manila.

The paper discusses how the D&D methodology addresses the need for an integrated, "discipline neutral" systems approach to agroforestry and various factors involved in the relative success ICRAF has experienced with the use of the D&D methodology by multidisciplinary scientific teams. As a technical contribution to a working group of social scientists and others concerned with interdisciplinary methodologies, the paper is intended to raise the level of international awareness about D&D, but it is not intended for general distribution to prospective users. (See Annex 9).

On a more practical level, aspects of the D&D methodology are now finding their way into simplified training materials for Village Polytechnics in Kenya, through ICRAF involvement with a Nairobi based project of the International Labour Organization. Drs. Rocheleau and Raintree have reviewed the training materials produced by this project and Dr. Rocheleau has authored four "learning elements" within the training module on "Choosing a Tree" which incorporate aspects of the D&D approach in a highly simplified way.

3.2 Kathama Site Activities

Development and testing of methodology for on-farm agroforestry trials continued during the quarter with a baseline soil survey and measurement of the biomass yield from alley cropping hedgerows on one farm. Dr. Rocheleau's work with voluntary agroforestry groups in Kathama now involves some 250 households. Four of the self-help nurseries started this quarter to collect seed and produce seedlings on their own for the first time. This is the kind of learning which must occur if agroforestry innovations are ever to be "self-spreading". Local dissemination of the approach being developed at Kathama took a major leap forward in this quarter with exchange visits between Kathama project participants and the leaders of some 28 self-help groups (with a total membership of nearly 2,000 people) from the Katisaa (Yatta Plateau) area of Machakos. Involvement of personnel of the Machakos Integrated Development Project in these exchanges increases the potential for wider dissemination of successful aspects of this "horizonal learning" approach to community participation in agroforestry trials. Eventual documentation of the case study information being generated by these activities will make the Kathama model available to agroforestry workers elsewhere in the world.

3.3. Activities in Siaya

Cooperation with the CARE Kenya Agroforestry Project continued this quarter with community and landscape level diagnostic and design activities carried out by Dr. Rocheleau and Remko Vonk (former ICRAF Research Assistant in the D&D Project, now with CARE Kenya). See Annex 10 for a sample of the results of group survey activities. This activity is part of the current effort in the D&D project to develop the methodology of larger scale D&D applications.

3.4 Collaboration with the SPOT Simulation Campaigne in Kenya

A new dimension was added to the "larger scale" D&D activity this quarter with the formulation of a plan of collaboration with the French SPOT satellite group now operating in Kenya. The Kathama research site, with

its four year's of accumulated data from D&D project, will provide "ground truth" information for comparison with the new high-resolution satellite imagery (now capable of resolving land use forms in the 10 to 20m size range). As a joint activity with the Land Evaluation Project in ICRAF's Systems Programme, D&D staff at Kathama will contribute to the testing of SPOT's ability to identify very small agroforestry land use features, possibly down to the level of individual trees. Such techniques may prove to be very powerful tools for large scale D&D applications. (See Annex 11)

4. AGROFORESTRY SYSTEMS INVENTORY PROJECT (P.K.R. Nair)

4.1 Data Collection

As indicated in the previous report, the date for completing data collection was extended beyond 31st March 1984. During the quarter, data sheets were received from several Regional Coordinators:

- Exhaustive four-volume, final report from Prof. von Maydell for the arid and semi-arid West Africa;
- Final report from SEARCA including report for the Philippines;
- Report for Ecuador, Dominican Republic and Nicaragua were received from CATIE with the promise that reports from other countries would be sent before the end of June 1984;
- Dr. Tejwani (RC, South Asia) has confirmed that all the work pending with him for the region would be completed and submitted by mid-July 1984.
- Dr. Baumer (RC for the Mediterranean and the Middle East) gave a summary report and completed questionnaires for two systems in the region.

Some voluntary reports were also received from other enthusiasts. These included:

- two descriptions from Sumatra, Indonesia
- one from Papua New Guinea
- one (up-dated) from Venezuela
- one from Ghana

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4.2 Meeting of the Nairobi-based Coordinators

A meeting was held on 04 May at ICRAF, attended by ICRAF Director, AFSI project staff (P.K. Nair & E. Fernandes) and Drs. M. Baumer and A. Getahun (RC for East, Central and humid West AFrica). Matters arising from the USAID Evaluation Team's visit in March 84 were discussed and the two RCs were requested to complete data collection as stipulated.

4.3 Data Evaluation

E. Fernandez visited Prof. Spedding and his group in the first fortnight of April. Together they examined the available (primary) data and found that the primary data received from various geographical and ecological regions, and collected by different people varied considerably in their details. They felt that the data needed to be transferred to a secondary data format for which a modified format was devised. A first draft is attached as Annex 12. The primary data are now being tranferred to this new format. These secondary data sheets will be more uniform and will facilitate computerization of data.

4.4 Data Bases

The data bases mentioned in the previous reports are being constantly improved and up-dated.

4.5 System Descriptions

During the quarter, the following system descriptions were completed and sent to the AF Systems Journal for publication.

No. 4: P.F. Fonzen and E. Oberholzer
Use of multipurpose trees in hill farming systems in Western Nepal

No. 5: P.T. Evans and J.S. Rombold
Paraiso (*Melia azedarach* var. "Gigante") woodlots: An Agroforestry alternative for the small farmer in Paraguay

No. 6: R.M. Bourke. Food, coffee and casuarina:
an agroforestry system from the Papua New Guinea highlands

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No. 7: M. de S. Liyanage, K.G. Tejwani and P.K.R. Nair. Coconut intercropping in Sri Lanka

No. 8: D.V. Johnson and P.K.R. Nair.
Perennial crop-based agroforestry systems in Northeast Brazil.

Copies of these papers are attached as Annexes 13-17.

4.6 Other Outputs

1. P.K. Nair and E. Fernandez gave two lectures with slide preparations on global overview of agroforestry systems and other aspects of AF systems inventory

   - to the participants of the USAID projects Energy Initiatives for Africa, Nairobi; 16 April - 25 May;

   - to the second ICRAF/USAID training course, Nairobi; 4-23 June.

2. A set of 20 colour transparencies of prominent and promising AF Systems around the world was prepared with appropriate short descriptions. and distributed to the participants to the second ICRAF/USAID training course, Nairobi.

3. The following paper by Nair, prepared by invitation, contains some results of the AF Systems inventory

   P.K.R. Nair 1984. Tropical agroforestry systems and practices. Chapter 14 *In* Furtado, J.I. and Ruddle, K. (Eds). Tropical Resource Ecology and Development. John Wiley, Chichester, England.

   (Copy of the paper is attached as Annex 18)

4. The two systems overview and description Tables contained in the above paper were distributed to the participants to the second ICRAF/USAID training course, Nairobi, June 1984, as basic resource documents.

5. E. Fernandez gave an account of the Chagga home gardens of Mt. Kilimanjaro, N. Tanzania in an interview for BBC World Service programme "The Farming World". The text is attached as Annex 19.

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4.7 Major Items of Work Planned for Next Quarter

- Data collection from the pacific Region;
- Continuation of data evaluation as indicated above;
- Preparation of more system descriptions.

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5. FINANCIAL STATEMENT

INTERNATIONAL COUNCIL FOR RESEARCH
IN AGROFORESTRY,
P.O. BOX 30677,
NAIROBI, KENYA

PROJECT FINANCIAL IMPLEMENTATION REPORT

PROJECT: 936-5545
COOPERATIVE AGREEMENT NO. DAN-5545-A-00-2076-00
AS OF

APPROVED BUDGET LINE ITEM	AMOUNT BUDGETED		DISBURSEMENTS (US$)			
	1	2	3	4	5	6
	US$	KSHS	Prior Cumulative	This Period	Cumulative Thro'	Estimate Next 90 days
1. Salaries	444,525	-	313,950	54,955	368,905	14,250
2. Consultants	104,000	-	78,777	16,536	95,313	10,000
3. Travel & Transportation	103,500	-	45,120	3,265	48,385	5,000
4. Equip. Materials & supplies	107,240	-	64,597	6,572	71,169	5,000
5. Participant training	63,400	-	24,850	31,180	56,030	-
6. Overhead	162,335		104,559	22,497	127,056	6,850
7. Evaluation	15,000	-	12,568	-	12,568	-
Total	1,000,000	-	644,421	135,005	779,426	41,100

Estimated disbursements thru (columns 5&6) 1984	$ 820,526
Less cash advances received thru/disbursments to/	$ 724,801
Cash advance/requested	$ 95,325

I certify that records and supporting payment documentd, eg. commercial invoices, receiving reports, inventory and property records areon file at ICRAF Headquarters (Nairobi) and are available for review by US Government representatives upon request.

Signature: Gatamah
Name: Karugor Gatamah
Title: Secretary/Treasurer
Date: July, 17 1984

Standard Form 1034
Revised January 1980
Department of the Treasury
I TFRM 4-2000
1034-110

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

VOUCHER NO.

U.S. DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION

Regional Financial Management
Centre for International
Development,
P.O. Box 30261, NAIROBI.

DATE VOUCHER PREPARED: 17th July, 1984

CONTRACT NUMBER AND DATE: DAN-5545-A-00-2076-00

REQUISITION NUMBER AND DATE: Sept. 14 1982 and amend No. 1 old Jan. 1983

SCHEDULE NO.

PAID BY

PAYEE'S NAME AND ADDRESS

International Council for Research in
Agroforestry,
P.O. Box 30677,
NAIROBI.

DATE INVOICE RECEIVED

DISCOUNT TERMS

PAYEE'S ACCOUNT NUMBER

SHIPPED FROM | TO | WEIGHT | GOVERNMENT B/L NUMBER

NUMBER AND DATE OF ORDER	DATE OF DELIVERY OR SERVICE	ARTICLES OR SERVICES (Enter description, item number of contract or Federal supply schedule, and other information deemed necessary)	QUANTITY	UNIT PRICE COST	UNIT PRICE PER	AMOUNT
		Advance payment for estimated expenditures for the period 1st July to 30th Sept. 1984 (see attached signed project implementation report)				US$ 95,325

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL US$. 95,325

PAYMENT:
- ☐ PROVISIONAL
- ☐ COMPLETE
- ☐ PARTIAL
- ☐ FINAL
- ☐ PROGRESS
- ☐ ADVANCE

APPROVED FOR =$

EXCHANGE RATE =$1.00

DIFFERENCES

BY [1]

TITLE

Amount verified; correct for

(Signature or initials)

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

(Date) (Authorized Certifying Officer)[2] (Title)

ACCOUNTING CLASSIFICATION

PAID BY

CHECK NUMBER ON ACCOUNT OF U.S. TREASURY

CHECK NUMBER ON (Name of bank)

CASH $ DATE

PAYEE [3]

[1] When stated in foreign currency, insert name of currency.
[2] If the ability to certify and authority to approve are combined in one person, one signature only is necessary; otherwise the approving officer will sign in the space provided, over his official title.
[3] When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example: "John Doe Company, per John Smith, Secretary", or "Treasurer", as the case may be.

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The information requested on this form is required under the provisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

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Annex 9

A SYSTEMS APPROACH TO AGROFORESTRY DIAGNOSIS AND DESIGN: ICRAF'S EXPERIENCE WITH AN INTERDISCIPLINARY METHODOLOGY

by

John B. Raintree

Prepared for presentation at the VI WORLD CONGRESS FOR RURAL SOCIOLOGY
Working Session No. 26: Interdisciplinary Collaboration in Rural
Development - Dream or Reality? Manila, 15-21 December 1984

April 1984

ICRAF

INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY
CONSEIL INTERNATIONAL POUR LA RECHERCHE EN AGROFORESTERIE
CONSEJO INTERNACIONAL PARA INVESTIGACION EN AGROSILVICULTURA

P.O. Box 30677, Nairobi, Kenya. Tel: 29867. Telex: 22048 Cable: ICRAF

A SYSTEMS APPROACH TO AGROFORESTRY DIAGNOSIS AND DESIGN: ICRAF'S EXPERIENCE WITH AN INTERDISCIPLINARY METHODOLOGY

SUMMARY

Agroforestry is an ancient system of land management, but a new field of organized scientific activity. Recently arisen to fill the gap in applied science created by the time honoured but artificial separation of agriculture, forestry and allied disciplines, agroforestry is an inherently interdisciplinary field. Although agroforestry research by multidisciplinary teams is the order of the day, the high degree of interdisciplinary synthesis which is needed to realize the full potential of agroforestry is not an easy goal to achieve. To complete the emerging paradigm for agroforestry research and development, a number of interdisciplinary methodologies are needed.

To answer part of this need, the multidisciplinary staff of the International Council for Research in Agroforestry (ICRAF) have been working since 1981 to develop a methodology for agroforestry Diagnosis and Design (D&D), as an aid to the identification of research and development priorities and as a basis for a coordinated interdisciplinary approach to project planning and implementation. Based on more than twenty test applications with international collaborators in a wide range of sites around the world, ICRAF has published two draft D&D methodology manuals and a number of case studies for wider review and comment.

This paper presents an introduction to the evolving D&D methodology and discusses key features of the interdisciplinary systems approach on which it is based. Beginning with a review of the requirements which must be satisfied by any methodology which seeks to catalyze an interdisciplinary approach to the improvement of land management systems, the paper goes on to explain the general conceptual and procedural framework of the D&D methodology, and concludes with an overview of ICRAF's experience in developing and disseminating this interdisciplinary approach.

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A SYSTEMS APPROACH TO AGROFORESTRY DIAGNOSIS AND DESIGN: ICRAF'S EXPERIENCE WITH AN INTERDISCIPLINARY METHODOLOGY

1. AGROFORESTRY AS AN INHERENTLY INTERDISCIPLINARY FIELD

1.1 Agroforestry Defined

It is customary to begin a paper on a new subject area with a definition of the field. As much as one would like to offer a universally accepted definition of agroforestry, alas, it must be acknowledged that there are almost as many definitions of agroforestry as there are people who deal with the subject (Editors, *Agroforestry Systems*, 1982). This diversity of viewpoint is in part due to the interdisciplinary nature of the field and, in fact, the history of attempts to define agroforestry reveals something of the disciplinary forces at work in the development of the field.

The first widely acknowledged attempt to outline the scope of the subject defined agroforestry as:

> ... a sustainable management system for land that increases overall production, combines agriculture crops, tree crops and forest plants and/or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population (Bene *et al.*, 1977).

This definition gives explicit recognition to the variety of biological components which may be combined in agroforestry systems and implicitly acknowledges the various historical roots of the agroforestry tradition in agronomy, tree crop horticulture, forestry and livestock sciences. By explicitly citing "sustainability" and "cultural compatibility" as criteria of agroforestry, this early definition also gives testimony to the formative role in agroforestry of two other disciplinary traditions: environmental/conservation and social science/rural development disciplines.

It is a *normative definition*, which states not merely what agroforestry is but what it *should be*, i.e. a land management system that is, by definition, *productive*, *sustainable* and *culturally appropriate*. Problems have arisen subsequently in maintaining a literal interpretation of this early normative definition. Strictly speaking, there is little justification for assuming that all land management systems which qualify as "agroforestry" from the standpoint of the combination of biological components (trees with herbaceous crops and/or animals) would *automatically* fulfill the above mentioned normative criteria. Poorly designed agroforestry systems, in fact, may fail on one or even all of these counts.

As scientific agroforestry emerges from the "awareness and enthusiasm" stage and begins to settle down to serious work, the tendency has been to retain these criteria as *attributes of good agroforestry design* while noting, however, that they must be *achieved* by the developers of agroforestry systems rather than merely *ascribed* to any system which

happens to meet the minimal definition of agroforestry. A more neutral and widely acceptable definition has been advanced which conceives of agroforestry as:

> ... an approach to land use in which woody plants are deliberately combined on the same land management unit with herbaceous crops and/or animals, either in some form of spatial arrangement or in sequence. The concept of an agroforestry system implies both ecological and economic interactions among the components of the system (after Lundgren, 1982).

The elevation of agroforestry to a field of study in its own right is based on the recognition of the need for an *integrated* approach to land use and the observation that many existing or yet to be developed land use systems all have, in their particular combination of components, a common denominator that is worth exploring and developing in a more systematic and scientific manner; namely, the deliberate use of the special productive and protective features of woody plants to increase, sustain and diversify the total output from the land (Lundgren and Raintree, 1983).

1.2 Multidisciplinarity and Interdisciplinarity in Agroforestry

A certain minimal degree of multidisciplinarity is virtually assured in agroforestry by the very nature and complexity of the subject, but the degree of interdisciplinary thinking that is needed to develop the full promise of the approach is not often easily acheived. In a field of applied science characterized by the study of interactions which cut across the traditional lines of disciplinary specialization it is not enough to understand each component in isolation. Nor is it sufficient, or even necessary, for purposes of good research to catalogue and study all conceivable interactions in detail -- an impossible objective in any event. What *is* needed for agroforestry to progress as an applied science is an interdisciplinary research paradigm which is capable of identifying crucial research priorities, based on a structured but flexible and cost-effective methodology for understanding those *critical interactions* which determine the ability of land management systems to achieve the purposes for which they are designed.

The need for this type of an approach to the organization of agroforestry research is clearly stated in the charter of the International Council for Research in Agroforestry (ICRAF) and the means for addressing it have been carefully built into the Council's institutional strategy (Steppler, 1981; Steppler and Raintree, 1983; Lundgren and Raintree, 1983) and its programme of work (ICRAF, 1983c). Other institutions and individuals active in agroforestry are coming to similar conclusions, but everyone faces the same general constraints on the achievement of a coherent interdisciplinary approach: *disciplinary biases* in the training of researchers, *institutional constraints* on the conduct of agroforestry research, *communication problems* between members of multidisciplinary research teams, and *lack of appropriate interdisciplinary methodologies.*

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To elaborate briefly on these constraints, the traditional *disciplinary biases* in the training of researchers has created a situation of acute shortage of well-rounded scientific manpower for broadly based approaches to agroforestry research. Although educational programmes are beginning to be developed to broaden the interdisciplinary training of agroforestry researchers (ICRAF, 1983), in the short and medium term most of the scientific and technical manpower available for agroforestry research and development will have been trained along traditional disciplinary lines. Even in the longer term it is likely that agroforestry workers will still need, in addition to their interdisciplinary training, a strong foundation in at least one of the major traditional disciplines. Discipline grounded "agroforestry generalists" may in time emerge from educational institutions, but the main strategy for meeting the scientific manpower requirements of agroforestry for the forseeable future will most likely be based on the fielding of *well-rounded multidisciplinary teams*, coordinated by interdisciplinary-minded team leaders. This trend is evident today in the multidisciplinary team approach which is becoming a standard feature of agroforestry project planning.

The ability to field such teams, however, is currently hampered by severe *institutional constraints*. In government institutions and universities, departments dealing with different aspects of land use are often separated by rigid institutional boundaries, often accentuated by fierce competition for scarce resources. Agroforestry as such typically has no single institutional base and the recruitment of an adequate multidisciplinary team must often depend upon fragile ad hoc arrangements for inter-institutional cooperation. While long term arrangements for institutionalizing agroforestry on a more permanent basis will have to be made (Steppler, 1981; Lundgren and Raintree, 1983; Catterson, 1982). the best hope for the short and medium term may be in the form of *projects* of prescribed duration, each with its own agroforestry-oriented budget and programme of work (Torres, 1983).

Even when these problems can be overcome and a secure framework established for a multidisciplinary team approach to agroforestry research and development, once the team is in the field enormous *communication problems* set in which, if not solved, will prevent the team from making the transition from *mere multidisciplinary* to *genuine interdisciplinarity* in its approach. With a few rare exceptions perhaps, any one who has ever sat down with a multidisciplinary group of scientists to thrash out a common interdisciplinary perspective will be familiar with the frustrations of trying to resolve the traditional differences of interest or perspective which are inherent in such groups. The problems are both cognitive and motivational in nature, but one has the feeling that the latter may be of overriding importance. Perhaps the best antidote to the pointless and often poisonous debates which arise in such contexts is to shift the whole activity out of the academy and into a real life field situation. Only when confronted by real and complex problems in urgent need of solution will individual team members be able to cross the *motivational threshold* which prevents them from submerging relatively minor disciplinary differences in favour of productive teamwork on the really major interdisciplinary problems and opportunities with which the field situation confronts them. There is nothing like a healthy dose of undiluted reality in the field to generate a completely new and refreshing set of problem-oriented priorities. Very often this is the *only* feasible way of integrating the human dimension into agroforestry research.

If this transition is successfully made, there may be no turning back. Scientists involved in this problem-solving or "mission-oriented" type of work often express a deeper sense of personal satisfaction with their work. Real problems are *harder*, not easier to solve than those derived from a purely theoretical or disciplinary orientation. Moreover, the inspiration afforded by the field situation for substantive theoretical or "pure science" contributions can be quite significant. Although the current emphasis on the interdisciplinary team approach in applied land management science can be seen as part of the larger society's strategy for coping with unprecedented human challenges (i.e. nothing less will suffice at this hour in human history), the high level of personal stimulation inherent in interdisciplinary work can itself provide sufficient psychological impetuous to keep the process going, once the threshold has been crossed.

All this is well and good, but experience indicates that *catalysts* are needed to assist multidisciplinary teams to cross the threshold of interdisciplinary activity. The field situation itself is one such catalyst, good will and a shared problem-solving motivation are also needed, but in the end little progress will be made unless the team can arrive at a shared and detailed blueprint of *how to proceed* in its investigation of the land management system at hand. This is where the need for an interdisciplinary *methodology* comes into the picture. A good methodology can bring the other catalysts into operation. Without such a methodology, no amount of good will and motivation will enable a multidiciplinary team to achieve a coherent interdisciplinary approach to the solution of complex land management problems.

The remainder of this paper is devoted to a discussion of one such methodology, the Diagnosis and Design (D&D) approach developed by ICRAF in collaboration with agroforestry workers around the world as a tool for agroforestry research and development projects.

2. AGROFORESTRY DIAGNOSIS AND DESIGN: AN INTERDISCIPLINARY SYSTEMS APPROACH

2.1 The State of the Art

How do you identify priorities and organize applied research in a field which has no research tradition? How do you insure a conscientious research-for-development orientation in a nascent subject like agroforestry which poses so many fascinating and unanswered questions of a purely academic nature? How do you avoid disciplinary or pet technology biases when designing agroforestry systems for rural development? What is the most efficient and logical sequence of steps to follow in analyzing existing land use situations to identify the real needs and potentials for agroforestry?

These are some of the questions faced by ICRAF's multidisciplinary staff in trying to develop a methodology for agroforestry Diagnosis and Design (D&D) as an aid to the formulation and implementation of relevant and cost-effective research and development programmes in agroforestry. Work to develop such a methodology was initiated at ICRAF in 1981. Now, after trial applications in over twenty sites in Kenya and elsewhere around the world (though ICRAF's Collaborative and

Special Projects Programme), the methodology has been tested and adapted to a wide range of environmental and socioeconomic circumstances and brought to a preliminary stage of completion in two draft manuals (ICRAF, 1983a, 1983b) which are currently being circulated for review and comment before being revised for wider distribution and testing. The object of this open-ended process is to continue to develop and refine the methodology on the basis of trial and user feedback until it reaches its potential as a genuinely useful and practical tool for agroforestry researchers and development workers in the field.

Examples of practical field applications of the methodology are given in a complementary series on *Case Studies in Agroforestry Diagnosis and Design*, published within ICRAF's Working Paper series in order to facilitate rapid dissemination of D&D results from around the world (see for example Raintree, 1983a; Torres and Raintree 1984; Hoekstra, 1984; Rocheleau and van den Hoek, 1984). The series also provides opportunities for publication of selected case studies resulting from application of the methodology by researchers outside of ICRAF.

To facilitate access to and comparison of D&D results from a wide range of sites, a computerized data bank of global D&D information is being set up at ICRAF offices in Nairobi. From time to time, analyses and book length collections of case study materials relating to particular environmental or problem-oriented themes will be published. Over time, hopefully, the analysis of case study information will assist in the development of agroforestry in a way which is analogous to the role played by case studies in the development of medical science.

The various outputs from the Diagnosis and Design Project at ICRAF represent one aspect of a coordinated effort to develop a full range of useful methodological tools and information banks to service the needs of the global community of agroforestry workers (see ICRAF 1983c for information on other developments).

2.2 Requirements for an Interdisciplinary Methodology: Ends and Means

The considerations evoked in the first section of this paper touch on fundamental aspects of the "charter" of interdisciplinary teams, but what specifically could we expect of an interdisciplinary methodology for agroforestry? What specific *ends* should it address, and what *means* might it use to achieve these ends? These questions from part of the essential background to the D&D methodology. Indeed, the working out of appropriate means-ends linkages is the fundamental core of any methodology development process. Before proceeding to more detailed methodological considerations, it may be useful to first indicate the general requirements which the D&D methodology attempts to meet. For the sake of brevity the various requirements are listed under only four major headings. An interdisciplinary methodology for agroforestry should:

1. Provide a neutral, comprehensive and generally acceptable overall framework for collaboration between all disciplines relevant to the identification and implementation of applied research to develop agroforestry's potential as a source of appropriate technology for improved land management systems.

2. Institutionalize an effective applied focus in technology-generating research by providing mechanisms for feedback and coordination between rigorous on-station experimentation and participatory on-site research and testing with the intended users of technological innovations.

3. Provide practical procedures for timely and cost-effective inputs to the identification, planning and implementation of interdisciplinary research and development projects.

4. Suggest ways of completing the research-for-development cycle by following through with adequate extension followup and continued adaptive research within the recommendation domain for new or improved technology.

Many other criteria could be listed but most of these, I would submit, are already implicit in the above short list of major objectives, or are explicitly elaborated in the specific methodological strategies and tactics which have been developed as means for achieving the identified ends (ICRAF, 1983a, 1983b; Raintree, 1983b). For example, learning from farmers, technology evaluation by adoption, and ability to assess the technological needs and opportunities of resource-poor farmers are all key elements of the new research-for-rural-development paradigm (Chambers, 1983) and critical elements of any adequate methodology for applied agroforestry, which are given priority and dealt with in some depth at various stages of the D&D process. In this brief introduction to the D&D methodology most of the crucial methodological detail must remain implicit. More detail is provided in the draft manuals (ICRAF, 1983a, 1983b), but even there the emphasis has been on describing *how* to implement the objectives of applied research-for-development in the case of agroforestry, rather than *that* these objectives should be addressed.

In partial fulfillment of the first of the criteria listed above, the emphasis in the D&D methodology on providing a basis for appropriate technology-generating and testing research is a direct consequence of the mission-oriented, impact-maximizing strategy which must be adopted if interdisciplinary activities are to have the kind of material effect on the land management scene which is expected of agroforestry (Raintree, 1983b). People are not fed, housed, kept warm or provided with the means to cook their food and satisfy other basic needs by journal articles or successful scientific careers. While technology is not the solution to every rural development or conservation problem, without technology there can be no lasting solutions; moreover, improperly conceived technologies may generate more problems than they solve. To be fruitful, research on improvement of land management systems must result in the *concrete technical means* by which people may be enabled to take greater control of their destiny and satisfy their primary production objectives. The ultimate practical aim of the D&D methodology is to get agroforestry out of the lecture halls, off the drawing boards and into the landscape of rural development. Hence, the D&D emphasis on generation of appropriate component technologies and land management systems.

With regard to the first and second criteria, it is crucial, for an impact-maximizing approach, to achieve a proper balance between *systems research* on the one hand and *component research* on the other. It is at the *technology interface* that these two types of research come together.

We will return to this point shortly, but for the moment let it be said that the failure of institutions to achieve a smooth running integration of these two types of research may be the single most important reason for the relatively low yield of society's investment in rural development through applied land management research.

Let us examine a familiar case in point. The adoption over the past decade of a Farming Systems Research (FSR) approach (Collinson, 1981; Hildebrand, 1981; Zanstra *et al.*, 1981; Shaner, *et al.*, 1982) by many international and national agricultural research institutions may be seen as part of society's effort to improve the return on its investment in applied agricultural research. Faced with mounting and interrelated problems of resource degradation and failing production systems throughout the developing world, international support for the Farming Systems approach is part of the global society's response to a crisis situation. In essence, the introduction of FSR as part of the overall research strategy of these institutions is an attempt to bring about a proper balance between systems research and component research, the lack of which was recognized as a constraint on the achievement of applied research and development goals.

The attempt to correct existing imbalances and broaden the research approach to focus more effectively on neglected aspects of farming systems has, in most cases, required the addition social scientists to existing multidisciplinary research teams. Unfortunately, the inevitable institutional "growing pains" involved in the adoption of FSR methodologies and the close association of social scientists with this institutional adjustment has in many institutions tended to divert the debate on the proper balance between systems and component research into unproductive lines based on a *false dichotomy* between social scientists and biotechnical scientists. Be that as it may, the real issue in the Farming Systems debate is not between the social vs. the biotechnical sciences, but between *discipline-oriented* vs. *systems-oriented* scientists of any disciplinary background. In other words, while the adoption of the FSR approach does indeed involve a very necessary and productive debate on the overall balance of disciplines in applied scientific research, the real issue is between *those applied scientists who derive their research objectives and satisfactions from disciplinary traditions and incentives* vs. *those who get their inspiration from attempting to satisfy the technological needs of real world farming systems.*

Until the real issue is taken up, the intrinsic complementarity between systems and component research in the technology generation effort will not be perceived, the interdisciplinary threshold will not be crossed, and multidisciplinary teams will fail to achieve "takeoff" to sustained interdisciplinary interaction. Ultimately, of course, the real losers will be the rural people themselves, insofar as this lack of institutional coherence retards the development of adequate interdisciplinary approaches to the solution of the complex land management problems which they are facing.

As the history of science tells us, obsolete paradigms are rarely ever conclusively "disproven," they are merely abandoned in favour of newer and more adequate ones (Kuhn, 1962). Agroforestry, lacking an established research tradition of its own, is in a unique position to learn from past experience and build a more adequate interdisciplinary approach into

the very foundations of its emerging research paradigm. What is needed to avoid unproductive impasses is a clear understanding of the conceptual basis for fruitful collaboration between component researchers and systems reseachers in the technology generation effort.

a)	Outer Environment ENDS → (Land Use System)	TECHNOLOGY	Inner Environment ← MEANS (Materials & Techniques)
b)	SYSTEMS RESEARCH — What is needed →	TECHNOLOGY DESIGN	← What is possible — COMPONENT RESEARCH
c)	Planning Stage • Diagnosis of system problems & potentials • Specification of technology needs	SYNTHESIS	• Appraisal of existing technology • Feasibility of new technology to meet identified needs
	Implementation Stage • In situ trial and evaluation of the appropriateness of new and existing technologies	RESYNTHESIS	• Component screening • Interaction and management studies • Data synthesis and establishment of "design curves"

Figure 1. Complementarity between systems and component research with respect to a) the definition of a particular technology, b) specifications for technology design, and c) inputs to the technology generation effort at project planning and implementation stages. The lefthand "systems" and righthand "component" portions of this diagram correspond, respectively, to the upper and lower circles of Figure 2 and, somewhat less precisely, to the lefthand "on-site" and righthand "on-station" boxes of Figure 3.

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The conceptual basis for the synthesis behind the D&D methodology was laid some years ago by Herbert Simon (1981) in his lucid discussion of the nature of technical artifacts. The essential complementarity between systems research and component research is revealed when we consider what is needed to define any particular technology (Figure 1). Any piece of technology in this sense (or specific application of technological knowledge) can be seen as an *interface between two environments:* an *outer environment* which defines the purpose and functional requirements which the technology serves within the larger system (for our purpose, the "land management system" of which the technology is a part) and an *inner environment* which is defined by the particular arrangement and mode of action of the constituent elements (components) by which it serves its purpose (i.e. the "nuts and bolts" of the technology). Both sets of specifications are necessary to completely define any particular piece of land management technology, one corresponding to the information provided by systems research (system requirements and functional specifications) and the other to that which is provided by component research (component selection and management specifications).

As a research manager at one of the CGIAR centres once put it, "You cannot have systems without components, but components without systems are meaningless" (Nores, personal communication). The methodological corollary to Simon's interface concept is that, in the effort to generate appropriate land management technology, the respective roles of *systems researchers* (social scientists, economists, land resource specialists, climatologists, cropping systems specialists, etc.) and *component researchers* (foresters, agronomists, horticulturalists, livestock specialists, plant pathologists, etc.) should be seen as entirely *complementary* and *mutually supportive*. If either input is neglected, the technical specifications remain incomplete and the likelihood of the technology finding a niche in the intended system is correspondingly lowered. Without both sets of specifications, the technology generation effort remains a hit-or-miss affair.

The schematic conception given in Figure 2 illustrates the role of diagnostic and design activities in a research-for-development programme based on active complementarity between component technology and systems research. Fruitful collaboration at the "technology assessment" interface might take the form of the following dialogue: Systems researcher to component researcher, "What have you got for System X?" Component researcher to systems researcher, "What do you need for System X?" A lively discussion would then ensue on the specifications (external "system" and internal "component") for technology which would be appropriate and feasible in the context of System X. In due course this would lead to the design of appropriate technology and the planning of research to develop and test the identified technology.

Needless to say, it is neither necessary nor likely that individual scientists can be neatly classified once and for all under one of these two researcher categories. In practice individual scientists may contribute to both types of research. In the final analysis, the conceptual synthesis which is necessary to generate appropriate technology must take the form of a shared construct in the minds of all concerned, but some division of labour between members of an interdisciplinary team may be invoked in the development of this construct.

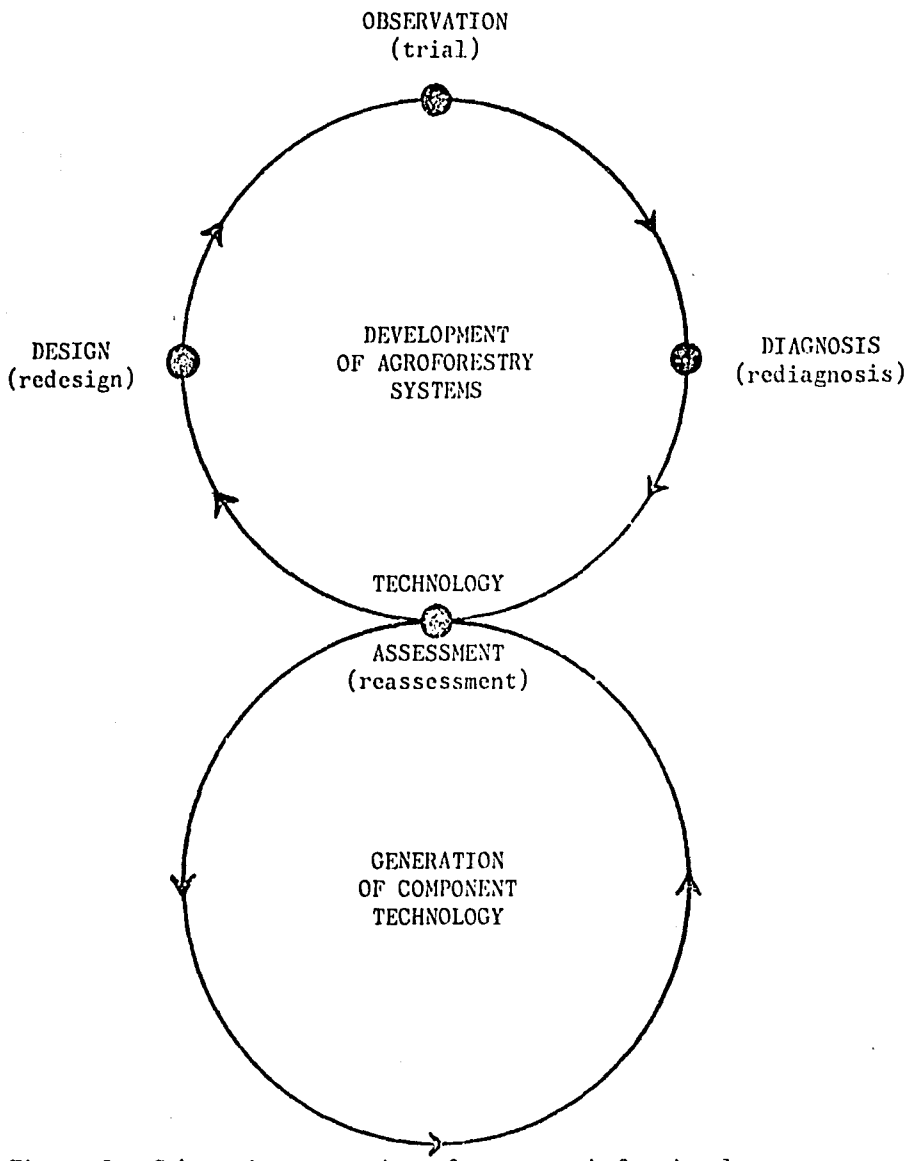

Figure 2. Schematic conception of a research-for-development programme based on complementarity between on-site systems research involving the iterative D&D process and component technology research involving rigorous experimental work on-station mainly but also, for some purposes, on-site. After the first round of the upper cycle (activities indicated in caps), the process is repeated as many times as needed to develop the system (activities indicated in parentheses). Interaction between the two circles at the "technology assessment" interface is designed to insure that the two mutually reinforcing types of research activity move in concert toward the shared goal of developing the system through the generation and application of appropriate technology.

If in principle there are no insuperable problems of interdisciplinary collaboration between researchers operating within the framework of the complementarity concept, there are nevertheless certain practical logistical constraints and requirements. The main one, which is implied the third criterion in our list of methodological requirements, is the limitation on time and personnel resources available for the type of survey work which is normally part of the discovery procedure needed to define the functional attributes and other system specifications for technology appropriate to a given land management system. We may refer to this as the "rapid appraisal" constraint, which has been the subject of considerable attention in recent years (Chambers, 1981; Longhurst, 1981; Pearce and Jones, 1981). Where research planning is a resource limited activity and where opportunities to accurately determine the appropriate direction for technology development are pre-empted by decisions taken in the press of time, systems researchers who ignore the rapid appraisal constraint do so at great peril to the success of their role in providing adequate system specifications for technology design.

Experience would indicate that lengthy survey work is neither necessary nor, in itself, sufficient to the information needs of the research planning phase of project development. The premium really is on *adequate analysis* of the system, rather than on any preconceived notion of the amount of survey work which ought on principle to be undertaken. Where the target land management system is already fairly well documented, very little survey may be needed to fill in the gaps in the knowledge required to derive appropriate technological specifications. Maximum use of available information can be made, but even where there is little or no baseline data, the information requirements of D&D can be rapidly met by steamlined survey procedures which involve senior members of the multidisciplinary R&D team directly in the collection of the essential information on which they will ultimately base their technology designs. Recalling what was previously said in section 1.2 about the need to focus on critical interactions, *essential information* may be defined as that which is needed to a) understand the critical means-ends linkages which govern the functioning of the target system (i.e. how the existing system works, its objectives, resources and technical means), b) diagnose its inherent problems and constraints (i.e. how *well* the system works), and c) assess the potential of the system to accommodate and benefit from discrete technological interventions of various types (leading to the development of design specifications).

The rapid appraisal approach to agroforestry Diagnosis and Design pertains mainly to the initial D&D exercise which is undertaken at the research planning stage to formulate an agroforestry R&D project. But diagnosis and design is a continuing, iterative process which can be repeated throughout the life of a technology-generating project to progressively deepen the diagnosis, assess the impact of introduced technology, and refine the prototype design to fit better the needs and potentials of the system. Once the project is on the ground with coordinated research activities on-station and on-site with farmers representative of the target land management system, the rapid appraisal constraint is no longer operative but the principles of efficient diagnosis and design continue to be applied as part of the projects "internal guidance system" (the basic mechanism in D&D for meeting the feedback requirements of criterion 2). Continuation of this same process into the

adaptive research activities of the extension stage of the project cycle is part of the D&D approach to satisfying the requirements of criterion 4.

The generalized flowchart given in Figure 3 illustrates the movement of information between the various research and development activities in an R&D project incorporating the D&D process, first as a basis for project formulation, then later as a means of coordinating feedback between on-going research activities (on-station and on-site) during the mid-project implementation stage, and finally as a means for handling feedback from a wider range of adaptive research trials at the dissemination stage. Figure 4 elaborates on the various roles served by the D&D process at different stages in the life cycle of a research and development project. The resulting process of "zeroing in" on an optimized land management system or component technology which the iterative use of D&D procedures can facilitate is illustrated by Figure 5.

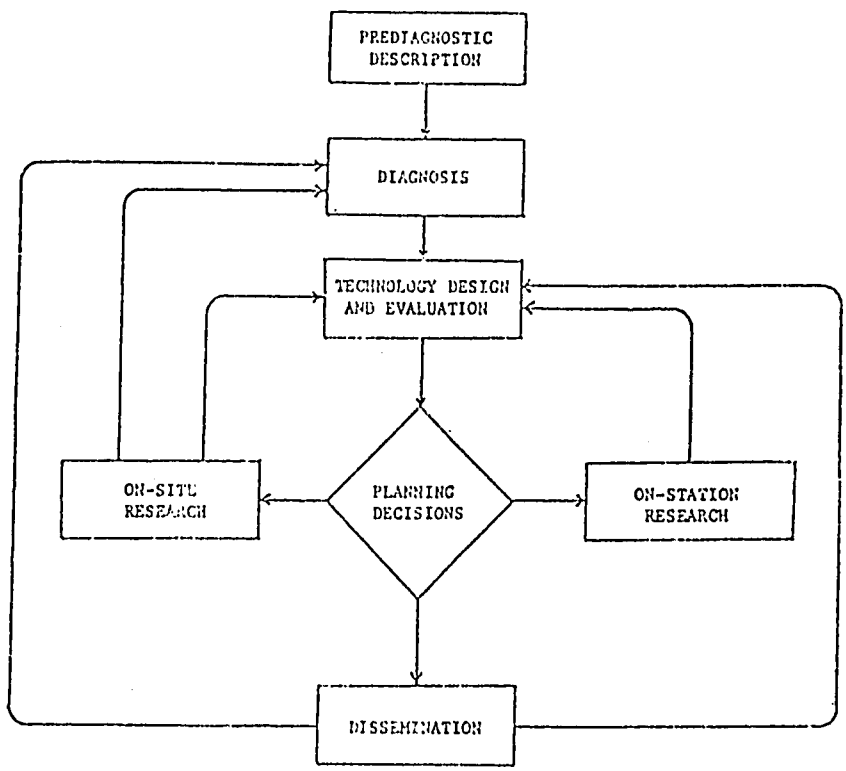

Figure 3. Components of project design incorporating the D&D process as part of the project's internal guidance system. Note feedback linkages.

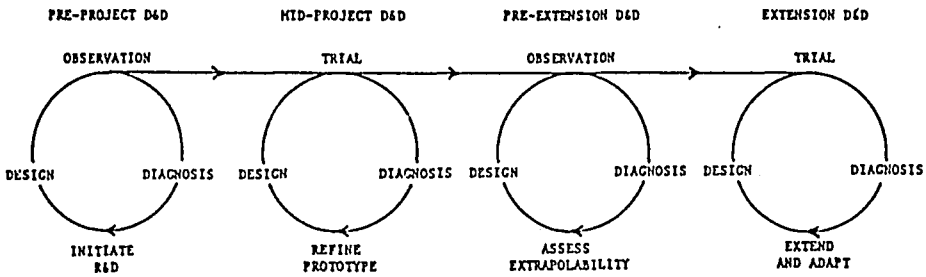

Figure 4. Repetition of the basic D&D process in different forms for different purposes at successive stages in the life of a technology generation and dissemination project.

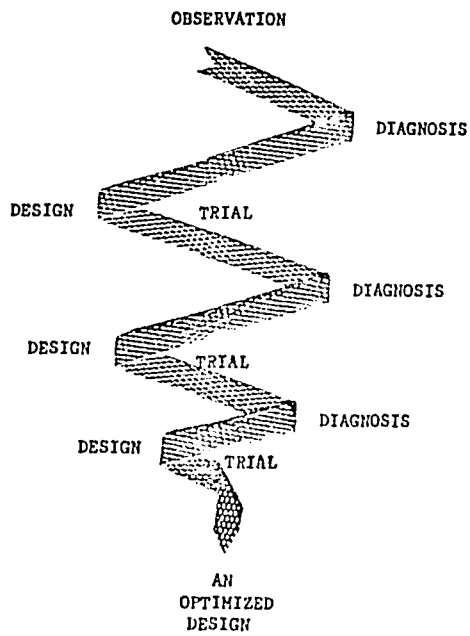

Figure 5. Beginning with an initial "best bet" design for a *generally appropriate* technology, the iterative D&D process leads, through a series of trial-and-error-reducing steps, toward the goal of a *specifically appropriate* technology for the target land use system.

2.3 Key Conceptual and Procedural Elements of the D&D Methodology

The foregoing discussion of methodological requirements and the general means by which the D&D methodology attempts to answer them has brought out some of the main principles of the approach. For purposes of this brief introduction to the methodology it still remains to give slightly more specificity to key elements in the conceptual and procedural framework of D&D applications.

Definition of "the System" for D&D Purposes

Given the concept of agroforestry as an approach to the improvement of land management systems, one of the prerequisites for successful application of the D&D methodology is a clear idea of what is meant by a "land management system." The concept adopted by the D&D methodology is based on the notion of a concrete, self-organizing "living system" as developed in General Systems Theory and widely applied in the biological and social sciences. This conception emphasizes analysis of the interactions among concrete system elements governed by the organized flow of matter, energy and information. It is distinguished from the alternative concept of "abstract systems" which deals with system variables at a more abstracted or idealized level of analysis (e.g. systems of causal relationships between components or states of concrete systems). Both types of systems analysis figure prominently in the D&D methodology, but the *definition* of "the system" for D&D purposes is based on the concrete systems approach.

Figure 6 illustrates the concept of the "land management system" which underlines the D&D approach. As shown in the illustration, the land management system, represented by the central pyramid, is part of the larger Man-Environment complex or "human ecosystem," represented by the square. At the top of the pyramid is Man, the manager, whose organizing influence (advertant or inadvertant) is felt throughout the human ecosystem but most clearly and directly expressed through the land management system. The base of the pyramid consist of those aspects of the Environment which are directly manipulated by Man to achieve his production objectives. The critical intervening variable in this interaction is the set of existing technical means by which the resource base is exploited to satisfy a given set of human purposes. In the functioning of the land management or production system, management flows down from Man (a movement of organizing information and energy) and production flows up from the resource base to Man (a movement of informed matter and energy).

The central point of this rather generalized dynamic model is that if any of the three main elements (human purpose, technology, resource base) were absent, the system would not function. The methodological corollary is that if any of the three essential elements are ignored, it will be impossible to *understand* how the system functions. Without such understanding, the effort to generate appropriate technology for the system will remain a hit-or-miss affair. Of course, it is not necessary to understand *everything* about the system in order to meet the information needs of good agroforestry design. What the model attempts to convey is a general notion of the kind of information that is essential for D&D purposes, i.e. an adequate knowledge of the means-ends linkages by which the land management system is organized to use available technology to exploit the resource base to satisfy human purposes.

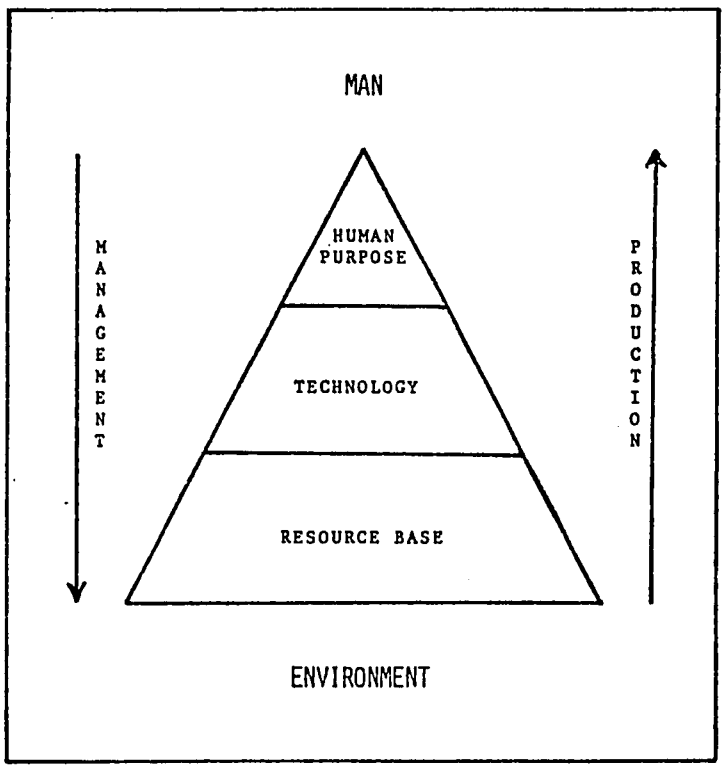

Figure 6. Concept of "the system" for D&D purposes. Within the "human ecosystem" represented by the square, the "land management system" which is the focal point of D&D activities is represented by the pyramid, illustrating the functional linkage of human purpose, technology and resources. An incomplete understanding of the system results if any of these three elements is ignored.

Just how the D&D methodology approaches this task is taken up shortly. For the moment another key aspect of the definition of "the system" for D&D purposes needs to be explained. Given the importance accorded in the above model to the central organizing role of human purposes, it follows that the analysis of the system must focus on the activities of the relevant *decision-making units* within the local human ecosystem. Identification of the focal units for D&D purposes gives additional specificity to the definition of the "land management system" and also defines the scale of relevant diagnostic and design procedures. Because the nature and composition of relevant decision-making units may vary widely from one geographical location to another, the D&D methodology has adopted a variable scale approach.

In most cases the primary focus for D&D activities will be on the *household land management unit*, i.e. the family farm, the household herd, or other elementary kinship-based production unit, for the simple reason that in most systems *this is where most of the major land management decisions are made* and it is these decisions which must be affected if agroforestry is to have any visible impact on the landscape.

Having said this, it must also be acknowledged that the household management unit may not be the only relevant decision-making unit to address in many cases. Agroforestry is an increasingly important management alternative for larger scale forest management units with their own forms of organization which must be taken into account. Even in farming systems applications many problems require a *larger-than-farm* scale of diagnosis and design. Watershed problems are a typical case in point, where erosion processes on one farm may originate or have impacts on other farms in the watershed. Boundaries between farms, roadsides, communal grazing areas, etc. are areas which may have problems which cannot be assigned to individual households and which may require larger scale landscape and community level solutions (Rocheleau and van den Hoek, 1984).

Smaller scale approaches to D&D may also be required to deal with *intra-household* level problems and potentials associated with the internal division of production responsibilities and opportunities (usually along sex role lines). These aspects may be particularly significant for agroforestry in regions where women, in addition to a heavy burden of domestic chores (food preparation, water supply, child care, etc.), may also have primary responsibility within the household for firewood collection, care of livestock and subsistence food production (Hoskins, 80; Fortmann and Rocheleau, forthcoming).

For all of these reasons, a flexible variable scale approach to D&D is required. A systematic attempt to assess the role of scale factors in agroforestry diagnosis and design is currently underway at ICRAF (Rocheleau, 1984) to supplement the basic guidelines for variable scale analysis given in the current D&D documentation (ICRAF, 1983b).

A Diagnostic Approach to Design

There is a saying in the medical profession that *"Diagnosis should precede treatment."* We wouldn't dream of entrusting our health to a medical practitioner who made a habit of prescribing treatments without first diagnosing what ails us. We expect the same approach from automobile mechanics. What a strange anomaly it is, then, that we have tended to accept a lesser standard of practice when it comes to treating

problems arising from man's use of the earth. The fundamental rationale for a diagnostic approach to agroforestry design, and indeed to all systematic attempts to rectify land management problems, is that this same standard of professional practice should apply when devising strategies for technological interventions in existing land management systems. The time, if ever it existed, when we could settle for a hit-or-miss approach to land management is long past.

Diagnosis, however, is not an end in itself. To have *impact* on the land use scene a diagnosis must be followed by an appropriate technological prescription. The diagnostic process, conceived as a "discovery procedure" is, nevertheless, usually the most direct and logic route to an appropriate agroforestry design. Intuitive leaps leading to very good agroforestry designs can, of course, occur, but the essential point is an epistemological one: how does one *know* that the design addresses the real needs and potentials of the system unless it is substantiated by a diagnosis of the system? For a careful, professional approach to agroforestry, it must be acknowledged that the ability to solve a problem begins with the ability to define precisely what the problem is (Steppler, 1981).

It is a common experience (grounded, one suspects, in some fundamental and evolutionarily significant feature of human cognition), that the very act of seeing a problem clearly can itself suggest the nature of the required solution. One could perhaps go so far as to suggest a methodological corollary to this observation: *If the analysis of a problem does not suggest at least the general outlines of a solution, then the analysis is not yet adequate and should be pursued further.* The D&D approach is, in essence, a kind of algorithm for evoking insights of this type into the connection between problems and solutions. As such, it really contains nothing fundamentally new, but merely suggests an efficient procedure for taking advantage of the remarkable human capacity for problem-solving which is somehow wired into the very nature of our thought processes. Troubleshooting the system: The particular form of the algorithm used in the D&D approach is suggested in a general way in Figures 2 - 5 and described in more detail for the project formulation stage of the D&D process in section 2.4 of this paper.

Criteria of Good Agroforestry Design

There is no substitute for good design. The world is littered with land management schemes that have failed because the intended users of new technologies did not take them up. Numerous factors are cited as reasons for failure, but one suspects that in most cases it is due, at base, to faulty design. The criteria adopted by the D&D methodology for good agroforestry design are threefold: *productivity, sustainability* and *adoptability.*

The *productivity* criterion is a self-evident and virtually universal measure of the success of any technological innovation. There is no need here to elaborate much on this criterion except to note that the D&D approach embodies a somewhat broader type of productivity assessment than is normal, partly due to the broad range of productivity improvements which are within the scope of agroforestry to address, and partly as an attempt to correct for an implicit bias in conventional productivity assessments toward commercialized systems of production. It is often tacitly assumed that the raising of cash income will automatically improve the ability of farmers to satisfy their consumption needs. Cash, in todays world is certainly a basic human need, but it

will not solve the problem of food and firewood shortage in areas characterized by *absolute scarcity* of these commodities. In other words, cash is not *always* readily convertible into forms which satisfy other basic needs. These needs must often be addressed directly and, since it is in many cases within the scope of agroforestry to do so, the survey protocols of the D&D methodology encourage its users to make an *independent assessment* of problems with respect to each of the several "basic needs supply subsystems" and the ability of the land management system to meet these needs either directly through home production or indirectly through cash transaction.

The needs which are considered basic and universal, and which therefore enter explicitly into the D&D protocols are: *food, water, energy, shelter, raw materials* for local industry, *cash* (for normal expenses), *savings/investments* (for extraodinary expenses or development), and *social production* (for ceremonial exchanges and the like). Although the adoption of this "basic needs approach" does give the D&D methodology the capability to effectively address the needs and problems of resource-poor farmers, it does not necessarily imply an anti-commercial bias. The assessment categories are there to be used as needed. In highly commercialized production systems, the D&D methodology directs attention mainly to improvement of the cash subsystem; in poorly developed market economies, the methodology may suggest opportunities to satisfy the basic needs more directly. Agroforestry can contribute in various ways to each of the above listed subsystems (see ICRAF, 1983b, pp. 157-160 for elaboration of this point).

The *sustainability* criterion in agroforestry design reflects the special ability of agroforestry to solve or mitigate resource degradation problems in respect to deforestation, soil and water conservation, fertility maintenance, pasture regeneration, etc. In the D&D methodology the conservation objectives of agroforestry are expressed in terms of *sustaining production* for the simple but expedient reason that most smallholders are primarily concerned with production objectives and only secondarily concerned, if at all, with conservation objectives. To awaken interest in new technology it is often necessary (and with multipurpose agroforestry systems, entirely possible) to offer packaged solutions which meet both conservation and production objectives simultaneously. Assessing the sustainability of the existing system and designing for sustainable agroforestry systems is, therefore, a primary feature of the D&D approach. It could be argued that this is a neglected aspect of other diagnostic methodologies in the land management field. In agroforestry, certainly, it is one which is harder to ignore.

The *adoptability* criterion is simply a way of operationalizing all of those social and economic factors which interact with the particular attributes of any given technology to determine whether or not the technology is acceptable to the intended users. If a given technology is not in fact adoptable by the intended users, there is not much point in it. An analogous observation is made by nutritionists in noting that the nutritional value of any food that is not eaten is zero, regardless of its chemical composition. It has been more or less standard practice in the applied land management sciences for researchers to take their inspiration for new technology from the research tradition itself, rather than from an assessment of the chances for a specific technology in a given land management system. The result, all too often, has

been the failure of the intended users to adopt the new technology because it simply does not fit their system (with its inherent technology biases, resource limitations and other constraints). Unfortunately, the tendency in such cases has usually been to blame the intended recipients or, in many cases, the extension system for failing to sell the new technology to the farmers. In most cases, however, it will be more productive to take cognizance of adoptability criteria in the *design* of technological innovations, in the first instance, and to build the appropriate characteristics into the new technology from the very start of the R&D process. This, in fact, is the explicit rationale behind the incorporation in the D&D methodology of adoptability as a criterion of good agroforestry design, on an equal footing with productivity and sustainability (see Raintree, 1983b for further discussion of adoption strategies in agroforestry).

2.4 Procedures for Project Formulation

As indicated above, the D&D methodology recommends an iterative process of diagnosis and design which continues throughout the entire life cycle of a research and development project, from the project planning stage, through the technology generation stage to the final stage of technology dissemination and adaptive research. In its present state of development, the existing draft documentation on the methodology gives primary emphasis to a set of general guidelines (ICRAF, 1983a) and optional detailed procedural suggestions and resource materials (ICRAF, 1983b) for the project planning stage of the project cycle. Additional guidelines and resources are currently being developed for later stages and will be incorporated into revised editions of the manuals. This staggered process of methodology development is partly due to the longer time required to gain experience with the latter stages of the project cycle, but partly also to the *priority* placed in this early period in the development of scientific agroforestry on the *formulation* of well-conceived projects.

In order to fit the needs, resources and levels of interest of the widest possible range of potential users, the D&D guidelines for project formulation are presently offered at three levels of detail.

Level 1. Minimal Guidelines

Guidelines at this minimal level of detail consist of little more than urging scientists and development workers to adhere to the basic principle that *diagnosis should precede treatment*. In applying this principle, there are many possible ways to proceed and workers are encouraged to use their ingenuity in devising ways and means appropriate to their own needs and resources. As long as one first takes the time to diagnose the target land use system *before* starting to design improvements for it, the minimal requirements of the D&D approach will be satisfied. Still, it may be helpful to pass along some useful hints and suggestions, based on ICRAF's experience with the approach, on how one might organize one's thinking in approaching this task. Table 1 suggests a four stage breakdown of the D&D process and the basic questions and key factors which ICRAF field teams have found useful to consider at each stage.

Table 1. Summary of level 1 guidelines for project formulation based on a four stage breakdown of the 'minimal' logic of the D&D process.

D&D STAGES	BASIC QUESTIONS TO ANSWER	KEY FACTORS TO CONSIDER	MODE OF INQUIRY
PREDIAGNOSTIC	HOW THE SYSTEM WORKS (what does it look like, how is it put together, how does it work?)	PRODUCTION OBJECTIVES AND STRATEGIES	SEEING THE SYSTEM
DIAGNOSTIC	HOW WELL THE SYSTEM WORKS (what are its problems, limiting constraints and dysfunctional syndromes?)	PROBLEMS IN MEETING OBJECTIVES CAUSES OF IDENTIFIED PROBLEMS	TROUBLESHOOTING THE SYSTEM DERIVING SPECIFICATIONS
DESIGN	HOW TO IMPROVE THE SYSTEM (what is needed to improve system performance?)	PROBLEM SOLVING OR PERFORMANCE ENHANCING INTERVENTIONS	BRAINSTORMING AND EVALUATING ALTERNATIVES
PLANNING	WHAT TO DO TO DEVELOP THE IMPROVED SYSTEM (what specific R&D actions are needed to develop and implement the envisaged improvements?)	R&D PRIORITIES	PROJECT PLANNING AND RESEARCH DESIGN

Level 2. Semi-detailed Guidelines

This is the level of detail contained in the draft *Guidelines for Agroforestry Diagnosis and Design* (ICRAF, 1983a, 25 pp.). At this level of detail the suggested procedures for project formulation emphasize a "rapid appraisal" approach (Chambers, 1981) and consist of a series of information gathering and analytical steps, leading logically from one to the next. This stepwise procedure entails an hierarchical progression from the general to the particular, which is designed to economize on time and effort by excluding irrelevant information from further consideration while developing a progressively sharper focus on *essential information*. By means of this structured but open-ended approach the level 2 guidelines attempt to avoid the seemingly endless and needlessly detailed data gathering task which is often characteristic of less structured approaches to systems analysis. In the level 2 methodology the four stage procedure suggested at level 1 is further subdivided into a series of 12 discrete steps, as follows:

Prediagnostic Stage (Steps 1 - 3)

This stage covers 1) background description of the study area, including diagnostically relevant aspects of the biophysical and socioeconomic environment, 2) differentiation and selection of land use systems within the study area for further D&D attention, and 3) preliminary description of diagnostically relevant aspects of the selected systems.

Diagnostic Stage (Steps 4 - 6)

This stage includes 4) diagnostic survey of the selected systems and relevant aspects of the environmental setting, 5) diagnostic analysis and identification of major land use problems and potentials, and 6) derivation of specifications for appropriate technology (including non-agroforestry options but with special attention to agroforestry potentials).

Technology Design Stage (Steps 7 - 9)

This stage involves 7) appraisal and selection of candidate technologies for possible inclusion in the design, 8) synthesis of a general design concept for an improved land use system and development, if possible, of initial 'best bet' designs for component technologies, and 9) ex ante evaluation and refinement of the proposed design. The activities of this stage may involve reiteration of the above steps.

Follow-up Planning Stage (Steps 10 - 12)

This stage covers 10) identification of research needed to develop and/or test the identified agroforestry technologies, 11) identification of areas needing further D&D attention in followup activities and 12) development of a detailed project implementation plan to carry out the envisaged R&D programme.

Table 2 presents a summary overview of the four stage process in slightly greater detail than Table 1. The *Guidelines* document itself goes a little further than what is shown here in the form of a step-by-step outline which suggests ways to proceed at each step, listing the expected *output* of each step, the relevant *sources of information*, a more detailed list of *factors to consider*, and a brief catalogue of *potentially useful tools* and materials.

Level 3. Detailed Guidelines

For users of the methodology who, when developing their own set of adapted procedures, might be desirous of having the benefit of the full range of detailed methodological suggestions which ICRAF's experienced multidisciplinary staff is currently able to provide, a third level of detail is given in the draft *Resources for Agroforestry Diagnosis and Design* (ICRAF, 1983b, 383 pp.). This collection of optional resource materials contains a more detailed set of procedural suggestions for each of the 12 steps in the level 2 methodology, along with over 35 resource modules describing useful diagnostic tools, analytical techniques and design materials for possible consultation at appropriate steps in the project formulation process. It would be unlikely, and indeed impossible in a "rapid appraisal" type of project formulation exercise, that all of the suggested procedures, tools and materials would be needed or used.

What must be emphasized, in any case, is that users of the D&D methodology in its more detailed form will almost always need to modify and adapt the suggested procedures to fit the particular application. This resource collection is designed to serve as a source of ideas to aid the user in this process. Many of the resource modules may also have value for agroforestry independent of the D&D process.

Table 2. Summary overview of level 2 project formulation guidelines showing how the D&D process relates to the concepts of the "land management system" and the "human ecosystem" illustrated in Figure 6. Stages of the D&D process are shown at the top of the table, the major analytical techniques at the bottom, and the key questions and factors to consider in each of the internal cells of the table.

		PREDIAGNOSTIC DESCRIPTION	DIAGNOSIS OF PROBLEMS & POTENTIALS	TECHNOLOGY DESIGN	FOLLOW UP PLANNING
HUMAN ECOSYSTEM	MAN	WHO IS INVOLVED? - LAND USERS - GOVERNMENT AUTHORITIES - OTHER INTERESTS	WHO HAS WHAT PROBLEMS? INTERACTIONS	FOR WHOM IS THE TECHNOLOGY INTENDED?	WHO SHOULD CARRY OUT THE NEEDED R&D WORK?
LAND USE SYSTEM	PURPOSE	MANAGEMENT (PRODUCTION/ CONSERVATION) OBJECTIVES OF THE DIFFERENT INTEREST GROUPS	PROBLEMS IN ACHIEVING MANAGEMENT OBJECTIVES, INAPPROPRIATE OBJECTIVES, STRATEGIES	SPECIFICATIONS FOR RELEVANT TECHNOLOGY	INSTITUTIONAL ARRANGEMENTS
	TECHNOLOGY	OVERVIEW OF TECHNICAL MEANS IN CURRENT USE	TECHNICAL CAUSES OF IDENTIFIED PROBLEMS, FUNCTIONAL POTENTIALS FOR TECHNICAL INTERVENTION IN THE SYSTEM	APPROPRIATE DESIGNS FOR IMPROVED LAND MANAGEMENT TECHNOLOGY	PLAN FOR TECHNOLOGY GENERATING R&D
	RESOURCES	OVERVIEW OF RESOURCE BASE	RESOURCE USE SUSTAINABILITY ASSESSMENT	RESOURCE REQUIREMENTS SUSTAINABILITY PROJECTION	PROJECT RESOURCES
	ENVIRONMENT	STRUCTURE AND FUNCTION OF THE HUMAN ECOSYSTEM/ LOCAL COMMUNITY	WIDER ENVIRONMENTAL IMPACTS	WIDER ENVIRONMENTAL IMPACTS	IDENTIFICATION OF WIDER RECOMMENDATION DOMAIN
		BASIC NEEDS ANALYSIS	TROUBLE-SHOOTING ANALYSIS; PRODUCTIVITY, SUSTAINABILITY, ADOPTABILITY CRITERIA	MEANS-ENDS ANALYSIS	ITERATIVE D&D PROCESS

D & D METHODOLOGY

Even in its most detailed form the D&D methodology cannot anticipate and provide answers (or even suggest ways to find answers) to every question which could arise in site-specific applications. At its present stage of development the D&D methodology is really a tool for an interdisciplinary *group process* approach to agroforestry diagnosis and design by a multidisciplinary team of experts (or, in some cases, by an interdisciplinary-minded individual with backup from a multidisciplinary pool of experts). Like all tools, the successful application of the D&D methodology relies heavily on the flexibility, competance and creativity of its users.

Level 4 Guidelines?

It is not clear just how far it is practical or useful to go in developing methodologies like D&D. Perhaps after the draft manuals are revised to incorporate user feedback it will be decided that ICRAF has gone far enough in this effort and the emphasis will then shift to the accumulation and analysis of case studies and the development of broader geographical perspectives on agroforestry needs and potentials. Certainly, it is only through *application* that the methodology will bear fruit in concrete form and have the kind of impact on the landscape of rural development that is intended. However that may be, it is still conceivable that this type of a methodological approach could aspire to a higher level of rigor and detail, as would be required to achieve the capability of *positive diagnosis* and *precision design*, with less reliance than at present on the knowledge and skill of particular multidisciplinary teams. Such a methodology, essentially an elaboration and refinement of level 3 procedures, would involve the use of system specific "diagnostic keys" and detailed "design algorithms," but it would require an empirical and theoretical understanding of agroforestry, indeed of land management systems in general, that is well beyond the present capabilities of the field. Whether or not this is an attainable, or even desirable, goal is a moot point, but perhaps it is one that should be kept in mind for the future.

3. PRELIMINARY EVALUATION OF ICRAF'S EXPERIENCE WITH THE D&D METHODOLOGY

It is much too early to give anything more than a very preliminary account of ICRAF's experience with the interdisciplinary D&D methodology. It is difficult, moreover, to evaluate that experience without sounding self-serving. Nevertheless, it does seem possible at this early stage to draw certain tentative and reasonably objective conclusions about ICRAF's experience in developing and applying the D&D methodology. It should be noted, however, that the perspective expressed here is the sole responsibility of the author and, while I have no reason to anticipate substantial disagreement from my colleagues, the following statements have not been subjected to systematic in-house review and, therefore, do not necessarily reflect the considered institutional judgement of ICRAF as a whole.

Let it be said straightaway that any success which may be attributed to the D&D methodology effort at ICRAF is in large measure due to the very favourable climate created for such work by the Council's mandate, institutional strategy and programme of work. The ultimate goal of ICRAF's work, as stated in its Charter, is "to improve the nutritional,

economic and social well-being of the peoples of developing countries by the promotion of agroforestry systems designed to result in better land use without detriment to the environment." As a research council without extensive field research facilities of its own, ICRAF's role is mainly to assist national and international institutions to develop and implement well-conceived research-for-development programmes in agroforestry The current programme of work, thus, emphasizes three main focal points:

1) the development of methodologies for identifying social, economic and ecological constraints in land-use systems and for assessing the potential of agroforestry technologies to overcome such constraints;

2) the systematic collation and assessment of agroforestry knowledge and the development of methods of studying and evaluating agroforestry technologies;

3) the efficient dissemination of methodologies and knowledge to scientists and development planners in the tropical and sub-tropical developing world (ICRAF, 1983c).

The need for a methodology to assist agroforestry workers to identify research and development priorities, based on a clear-eyed assessment of agroforestry-related constraints and potentials in existing land use systems, was identified as a priority focus for the Council early in the development of its institutional strategy (Steppler, 1981). Consequently, the D&D work was initiated in 1981 and later formalized as a project which received a major share of ICRAF's personnel and financial resources within the overall programme of work. A key element of ICRAF's strategy was to recruit a multidisciplinary team of 15 or 16 scientists whose first task would be to pool their collective experience to develop such a methodology.

3.1 In-House Development Phase

A brief discussion of some of the key elements of the institutional milieu in which the D&D methodology was developed may be of some relevance to the theme of this congress. In the first instance, the very complexity of agroforestry as an approach to the development of improved land management systems created an unusually favourable climate for a systems perspective among ICRAF's scientific staff. The newness of the field, lacking strong disciplinary conceptions of business-as-usual and, indeed, possessed of a kind of revolutionary clan, was no doubt another important and very favourable factor in the setting in which D&D developed. Few, if any, of the current systems methodologies in the land management field have enjoyed such a favourable institutional setting.

At the initiation of concerted D&D development activities in early 1981, the senior staff consisted of the Interim Director General and four scientists. While this might seem an inordinantly small staff complement for an organization with such a large mandate, it did promote an unusually intense and fruitful interaction among the scientific staff. The long, almost continuous, and sometimes very animated discussions which occured in this "think tank" atmosphere laid a sound foundation of shared interdisciplinary understanding which has formed the basis for much of ICRAF's subsequent work.

Early in the D&D methodology development two of ICRAF's scientists joined forces to spearhead the methodology development effort: an ecological anthropologist (later named project leader) with training in tree crop horticulture and psychology and a strong technology bent, and a livestock/range management scientist with an early background in agronomy and considerable experience in the management field. Two points are worth noting here: First, the interdisciplinarity of the individuals themselves, and secondly, the basic social science-biological science complementarity between these individuals, which in effect invoked the "pairing principle" which has figured so prominently in many of the Farming Systems methodologies. Another important element in the early D&D equation was the strong committment of this core team to the "new professionalism" (Chambers, 1983) of the research-for-development paradigm. The general committment of the Council as a whole to the ideal of an *applied* agroforestry science and the critical support of the other staff members (a horticulturalist and an agronomist) constituted a rich nutrient broth for the nascent D&D methodology. It was during this period that the basic framework for the D&D methodology was laid down.

One further element of the early methodology development work which was absolutely *crucial* to its success was exposure of the D&D team to realistic field conditions. Most of the early applications took place in Kenya at a variety of sites representing a range of ecological and socioeconomic conditions. One of these sites was developed as a special project site for in-house methodology development work and is now into its fourth year of on-farm agroforestry trials (Lundgren and Raintree, 1983; Rocheleau and van den Hoek, 1984; Vonk, forthcoming).

Gradually as other disciplines were added, notably a farm economist who brought fresh insights and greater rigor to the methodology and a forester who supplied an essential missing element, the basic framework of the methodology was fleshed out in greater detail and multidisciplinary rigor. It was not until 1983, however, that the full complement of disciplines originally envisaged for ICRAF's multidisciplinary team was reached (see ICRAF, 1983c for a listing of the more than 10 disciplines represented in ICRAF's current complement of 18 senior scientific and professional staff members). With the addition of a bioclimatologist, a land evaluation expert and a geographer/systems ecologist, the D&D methodology project was able to draw on a multidisciplinary staff whose breadth and sophistication is unlikely to be equalled anywhere else in the agroforestry field. This might, at first glance, seem to indicate a constraint on the application of the D&D methodology outside of ICRAF where such well-rounded multidisciplinary teams are rare, but this would be an erroneous conclusion since, as everyone knows, there is an enormous difference between the *development* of a methodology and its *application* by users. Right from the beginning, ICRAF's institutional strategy has distinguished three phases in the development of any of its methodologies:

Phase 1: Development of the in-house *capability* to accomplish a particular methodological objective

Phase 2: Expansion of ICRAF's in-house *capacity* to carry out a sufficient amount of methodology application work (as a service to clients)

Phase 3: Attainment of the status of a fullfledged *methodology* by transfer of the developed methodological capability to others for independent application (i.e. through documentation and/or training)

The D&D methodology is in the early stages of Phase 3. Conceived from the start as an activity which would involve the collaboration of potential users of the methodology in its development, the D&D methodology will not be complete until the current review period is over and suggested improvements have been incorporated into revised versions of the present draft manuals.

3.2 Dissemination Phase

There has been a high degree of overlap between the development and dissemination phases of the D&D methodology, inasmuch as the development of the methodology was largely accomplished through trial application and refinement at a range of sites around the world. Most of these applications have been organized under the umbrella of ICRAF's Collaborative and Special Projects Programme (COSPRO) and have involved collaboration of ICRAF scientists with local multidisciplinary teams of national and international scientists and, therefore, automatically involved dissemination of the evolving methodology. This repeated exposure to new ecological and socioeconomic circumstances, along with the feedback received from scientists representative of the methodology's main client group, has been a key element in the elaboration and refinement of the methodology. Few farming systems methodologies have been exposed to such a wide range of geographical conditions and user feedback.

For the purposes of this congress it may be instructive to consider how scientists exposed to the D&D methodology as part of the COSPRO project formulation experience have responded to the approach. The typical initial reaction to the methodology has been one of scepticism. "Is all this really necessary?" is the typical initial comment, recently expressed by an Indian scientist at the beginning of a D&D exercise in the Himalayas. Scientists have been formulating research projects without the benefit of the D&D methodology for years and the initial response is characteristic of scientists' reaction to what they often perceive as an intrusion on "business-as-usual" in a form which, at least implicitly, seems to call their professional competance into question. For the most part, the scientists recruited by their superiors for participation in ICRAF led D&D training-cum-project-formulation exercises are there not because of a burning interest on their part in improving their ability to identify meaningful priorities for applied agroforestry research, but because the need for such improvement has been recognized by higher management levels in their organizations. This is what one would expect. Research managers are more directly exposed to political demands for practical "results" that are part of society's response to the crisis situation facing many developing countries; while scientists, still relatively secure within the present system of disciplinary rewards, are sheltered from these pressures.

Be that as it may, given the long gestation period for the agroforestry technologies initiated by the D&D process, one of the few sources of empirical confirmation of the validity of the D&D process which we can presently offer is the fact that scientists initially expressing scepticism regarding the methodology, at the conclusion of the typical two week field exercise consistently express acceptance of and often real enthusiasm for the approach. Quite often it is the most vociferous sceptics who become the most vigorous champions of D&D. The phenomenon is so striking that one is tempted to compare it to the psychology of the classical "conversion experience."

The typical comment at the conclusion of a D&D field experience is on the order of "You know, I really wasn't too impressed with all this D&D business to start with, but I really did learn a whole new way of thinking about my research AND it wasn't really all that complicated or time consuming. It will be useful to me in my future agroforestry work."

Of course, the reaction is not always so positive. Individual scientists are differentially susceptible to innovations in methodology. In trying to discover whether there are any patterns in the response to D&D, we don't seem to find any clear cut disciplinary biases. Some soils scientists and foresters are as receptive to D&D as many economists and sociologists. The only clear pattern of resistance to D&D that we can presently discern is in cases where the individual has a strong personal committment to some "rival" methodology or deep ego involvement in previous work of a similar nature at the site. In the former case, the resistance may be misplaced, since ICRAF has never claimed to be in exclusive possession of the methodological holy grail. There are many ways to skin a cat, and the D&D methodology has always been presented as only one, perhaps more than usually systematic and efficient, example of what is after all a very general and fundamental problem-solving approach. In the latter case, we are confronted with a more delicate problem, which may indicate the need for caution in accepting the host country's nomination of a D&D training site at which there is a long history of prior scientific involvement, particularly when demonstrating the methodology for the first time in a country. In some cases it won't matter, but normally such sites involve psychological complexities that are best avoided in training exercises.

What, in fact, do participants in ICRAF led D&D demonstrations actually take away with them from the experience? What indications are there that D&D is being successfully adopted and adapted for independent service in host country institutions? Several D&D-based agroforestry research and development projects are underway at various places in the developing world and certain countries and regional research organizations have expressed the intention of adopting the D&D methodology as a basis for project formulation in national and regional agroforestry research networks but it is simply too early for the methodology to have diffused outward from its point of introduction and, therefore, too early to evaluate the actual adoption and adaptation process. Likewise with the ultimate impact of the methodology on the agroforestry landscape.

It is not too early, however, to profit in the methodology refinement process from early feedback on the D&D approach received from collaborators in the field, participants in ICRAF training courses which prominently feature the D&D methodology, and comments and suggestions received from reviewers of the current draft methodology documents. The positive aspects of the methodology more-or-less speak for themselves. Let us concentrate, instead, on the negative feedback, since this is the source of valuable course correction information. What are the difficulties users have with the methodology and/or its current forms of presentation?

One relevant point is based more on observation of first time D&D participants rather than comments received. To handle the complexity of the on-the-spot data processing task involved in the rapid appraisal of complex land management problems and potentials, the D&D methodology relies on a flexible but structured "first things first" approach. In

developing the methodology through repeated trial application, we have arrived at what seems to be a logical sequence of steps for an efficient and timely procedure. While the methodology allows and suggests flexibility in dealing with this progression, the general direction of movement (i.e. from general to particular and from diagnosis to design) can be ignored only at great peril to the timely completion of a coherent exercise. Some such "blueprint" for the exercise, adapted and agreed upon by the participating scientists at the outset, is a crucial requirement for fruitful multidisciplinary collaboration. Without it, everyone simply goes off in a different direction. The problem is that, even after having agreed on the procedural agenda, many scientists seem to have trouble sticking to it. As with all "committee" processes, a strong chairman who is thoroughly familiar with the demands of his role as leader of a D&D exercise is a must. The larger the group, the stronger the leadership needed. ICRAF's experience, consistent with the general findings of small group psychology, is that a team of about 5 or 6 scientists is about right for a smooth application of the D&D group process methodology. If a larger group is involved, it is best broken down into teams of about this size.

Part of the problem, if one may be allowed a bit of speculation on the cognitive processes involved, seems to be a lack of prior training in structured approaches to data. The concept of "structured programming" in the computer field is the clearest example of what we mean by a structured approach to problem solving: to tackle a complex, non-linear data processing task, it is helpful to first break the problem down into a set of smaller problems, blockout the main analytical tasks, and *then* proceed to work out the details. The advantages of this "top down" structured progression from the general to the particular are so striking, as compared to just "muddling through," that it really must be considered an essential ingredient of a rapid appraisal approach to systems analysis. The more complex the system and the shorter the time alloted to the task, the greater the need to stick to a structured approach.

This doesn't necessarily mean following the detailed D&D guidelines to the letter, but it does require an understanding of the general concept and technique of structured systems analysis, at least on the part of the team leader, and the grace and goodwill of the team in sticking to the agenda. The most common problem, often causing great frustration to those team members who have caught onto the approach and are trying diligently to keep the discussion focused, is that every team seems to include at least some members who are unable or unwilling to stick to business. The major disruptive cognitive factor is the tendency to proceed directly into detailed treatment of one aspect of the system (often someone's speciality area) before bringing the analysis of other interrelated aspects of the system to a comparable point. While they may agree to it in principle, in practice many first time D&D participants have difficulty in setting aside a problem and coming back to it later. This is not an insuperable difficulty, but it is one that needs the attention of a good interdisciplinary-minded group leader.

As regards feedback on the current draft documentation of the D&D methodology, we have been confronted with a bit of a paradox. On the one hand, many reviewers have suggested that the documentation needs to be shortened and simplified, while on the other hand, there are some who have expressed the desire for *more detailed* guidelines on particular aspects. Before simply accepting Abraham Lincoln's dictum

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that "You can't please all of the people all of the time," ICRAF's writers will attempt to effect a reasonable compromise in the upcoming revision process. Our feeling is that both demands need to be satisfied, and that is why we will attempt to improve the documentation without changing the current two volume draft manual format (short form *Guidelines* plus optional *Resources* collection). In this regard, it is pertinent to note that the individual users' demand for written documentation seems to increase with increasing acceptance of the general approach. In the developing country context, where the printed word seems to exert a less dominant influence on the scientific subculture than in more developed countries, it may be too optimistic to expect first time D&D team members to read even the short form *Guidelines* before the field exercise; whereas, *after* the exercise, once the general approach has been grasped and the relevance of the more detailed guidelines and resource materials more readily perceived, the demand for more detailed documentation of the suggested procedures and analytical tools may be expected to rise sharply. This suggests the primacy of a "hands-on" approach to D&D training, in the first instance, with written documentation playing a secondary, backstopping role.

Once again, it may be worth pointing out the extraordinary impact of the *field situation* on scientists who have previously confined themselves to research stations. For many of them it may be the first time they've really *seen* a village in terms intimately related to their research concerns. The psychological impact of just being in the village (surrounded by real people with real and unignorable problems) is enormous, but the main impact comes with the realization that *one is there for scientifically respectable purposes* which may, in future, be a factor in the success of one's career. This reaction is often indicated by the somewhat bemused or occasionally stupified expressions one reads on the face of such scientists in the first day or two of fieldwork. What a relief it is then to discover, after another couple of days, that the research improving process really isn't that difficult to carry out.

Having said that, it must still be acknoledged that there may be a tradeoff in any methodology, as in the technology-generation process itself, between professional standards of *technical adequacy* and the pragmatic standard of *easy adoptability*. While the latter criterion must be satisfied if a methodology is to have any chance of widespread adoption by scientists, compromises with respect to the technical complexity of the methodology can only be pushed so far without endangering the overriding objective of *solving the complex land management problems of rural people*. The reason these problems have proven so resistant to more casual approaches is that, in many cases, they simply *are* rather difficult to diagnose and solve. It is a bit superficial to insist on too much simplicity in methodologies for solving complex problems.

Paradoxically, it often seems to be the representatives of aid *donor organizations* who argue most forcefully for the lowering of professional standards in order to ease the adoption of systems methodologies by developing country scientists. These same organizations have played a major role in promoting the general policy changes behind the new research-for-development emphasis in developing countries. It would be good of them now to follow through with well orchestrated support for the methodologies which have arisen to meet the more stringent objectives of the new policies.

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The "new professionalism" (Chambers, 1983) demands higher, not lower standards of applied scientific excellence. If, in the final analysis, methodologies like D&D entail an unavoidable conflict of interest between scientists and the people they are commissioned to serve, it is clear whom we must ask to shoulder the additional burden. In thinking about how much room there is for improvement in this regard, I am reminded of a developing country scientist who once asked me "When is ICRAF going to put out a *short* description of the D&D methodology?" "But the *Guidelines* are only 25 pages," I answered in bewilderment. "Ah yes," he said, "but they are A-4 size pages!"

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Annex 13

USE OF MULTIPURPOSE TREES IN HILL FARMING SYSTEMS IN WESTERN NEPAL

By

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USE OF MULTIPURPOSE TREES IN HILL FARMING SYSTEMS IN WESTERN NEPAL

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ABSTRACT

A large number of multipurpose trees and shrubs are deliberately retained and/or incorporated on farms in the subsistence farming systems on the steep slopes in parts of Nepal. The woody perennials are maintained in contour strips across the slopes and around the fields. The greatest contribution of these trees is their protective function in reducing the erosion hazards and thereby making crop production possible in those steep slopes where profitable cropping would otherwise be extremely difficult. Based on a case study in two villages of the Western Development Region, this paper presents some data on basic farm management aspects, production of crops and other components, etc. of the system . The performance of the system is assessed and its merits and weaknesses highlighted in the paper.

Although the hill farming system extends over quite a large area and accounts for a large number of Nepal's population, it has not received any research attention nor benefitted by any scientific innovations. Improvement possibilities in terms of component technologies as well as farming systems including the incorporation of the several locally available medicinal plants are indicated in the paper.

Key words: Nepal, Agroforestry,
multipurpose trees,
hill farming,
erosion control,
medicinal plants

1. INTRODUCTION

Nepal, located on the southern slopes of the Himalayas, extends from the Gangetic plain in the south, and occupies one-third of the entire length of the Himalayan range. The country has a rectangular shape, approximately 830 km long (east-west) and 200 km broad (north-south) and has a total land area of 147,141 km. Within this short span of distance are remarkable altitudinal variations which range from a mere 50 m a.s.l. at the southern foot hills to well over 8,000 m a.s.l. at the northern crest line. The monsoonic pattern which indicates the total precipitation of the country clearly differentiates the east Himalayan region with the heavily rained forest from its western relatively scanty rained dry forest. More than 15 million people of different ethnic origin live in this Hindu kingdom.

Nepal is divided into five administrative units or Development Regions, viz., Far Western, Mid Western, Central and Eastern Regions. This paper is based on a survey of existing agroforestry systems of the hills of the Western Development Region. However, among the different Development Regions, there are many similarities in terms of land-use patterns and socio-economic characteristics, the site-specific variations being brought about by local factors such as aspect of slope (north- or south facing), foot hill (deep soil) vs hill-top (shallow, poor soil), altitude, etc. Therefore the system/practice described here can be taken as fairly representative for over 50 percent of the area of Nepal.

2. GENERAL DESCRIPTION OF THE AREA

The Western Region extends from the Terai lowland (150 m) to the Himalayas (Annapurna, Dhaulagiri - 8172 m). The

system described here are found in 500-2500 m altitude range. The climate is warm temperate with heavy monsoon rains between June and September, when 80-90 percent of the annual rainfall is received. The total quantity of rain varies widely depending on altitude and topography, ranging from 1000 to 2000 mm per annum in areas of about 1000 m altitude.

The soils, developed from a complex jumble of phyllites, shists, quartzites, granites and limestones are generally poor for agriculture. They are deeply weathered, containing only little organic matter and having a very low capacity to retain moisture and nutrients. In addition, they are prone to serious erosion hazards if not managed carefully: an annual soil loss of more than 12t $ha^{-1}yr^{-1}$, equivalent to 0.8 mm of the top soil, has been estimated (Tinau Watershed Project - TWP Management Plan).

Climax vegetation also varies according to altitude and topography: in the lower sites (less than 1000 m) mixed, evergreen, broadleaved forests of the *Shorea robusta*-type prevail; at higher elevations, broadleaved or pure coniferous forests are found with *Pinus roxburghii* as the predominant species. Fig. 1 shows the relationship between altitude, ecology and land use patterns. In general, the steeper the slopes, the more the proportion of forests preserved; the higher the rainfall, the more the agricultural activity. Data on land use pattern for Palpa District of Western Region show the following figures:

FIG. 1

irrigated (bari) land - 6.2%

non-irrigated (khet) land - 26.0%

grassland - 3.2%

forest - 37.7%

scrub and bush - 24.4%

other forms of land use - 2.5%

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An eye-catching characteristic of the foothills and gentle slopes is the terraces dug with untold difficulty by the farming families. Slopes too steep for terraces show a dense network of tree strips with sloping fields in between. Communal grazing land is also found on land of low productivity but close to villages. Very steep slopes, tophills and areas away from settlements are stocked with forests most of which have been highly degraded. Fig. 2 gives a general view of the landscape.

FIG.2

Despite its relatively inhospitable conditions, the area is densely populated, with more than 100 persons per km^2 and an annual population growth rate of more than 2.5 percent. Ninetythree percent of the people have to make their livelihood from agriculture and related activities.

The agroforestry practices that are commonly found in the area are use of shrubs for live fences around farmlands, pasture (grazing) in forest area and use of strips of multipurpose trees and shrubs around moderately-sloping (20-30 percent slope) fields. This last-mentioned practice of incorporations of multipurpose trees and shrubs is the subject of further description in this paper. The data presented here are based on a case study conducted by E. Oberholzer in two representative villages in Palpa District.

3. STRUCTURE OF THE SYSTEM

The main components of this land-use system are field crops, trees/shrubs and animals.

3.1. Crops

Major crops are maize *(Zea mays)*, various pulses *(Phaseolus* spp., *Vigna unguiculata*, *Glycine max*,etc.), finger millet *(Eleusine coracana)*, vegetables, rape seed *(Brassica napus)*, wheat *(Triticum aestivum)*, barley *(Hordeum* sp.), and

buckwheat (*Poygonum* sp.). Around the houses, various vegetables and banana are grown, mainly for household consumption.

3.2. Trees/Shrubs

Several trees and shrubs can be found on the farmlands (terraces). Most of them were not planted, but deliberately preserved/retained when the terraces were built. The species found most commonly on farmlands are listed in Table 1, of which the first ten species constitute roughly two-thirds of all such woody perennials. Evidently these are the species that are preferred by the farmers for their multiple outputs (fodder, fuel, fruits, timber, fence posts, etc.).

TABLE 1

In addition to these trees and shrubs, public (communal/governmental) forests and grassland in the vicinity provide 30 percent of the fodder requirements and 70 percent of the firewood needs of the villagers.

3.3. Animals

The Table below indicates the average number of livestock per household:

	No	Uses*
Cows	1.4	manure milk, religious needs
Oxen	1.3	draught, manure
She-buffaloes	1.3	milk manure
He-buffaloes	0.1	draught, manure, meat
Goats	2.6	meat, manure
Pigs	1.6	meat
Poultry	5.8	eggs, meat

* In addition to these uses, the animals are also sold in times of cash needs.

3.4. Arrangement of Components

The cropping systems are different in the non-irrigated (bari) and irrigated (khet) lands. The cultivation on the sloping bari land is very labour-intensive. Maize is the most common summer crop, and it is grown as a sole crop or in mixed/relay cropping sequences. On the irrigated (khet) lands, one crop of rice is cultivated as a sole crop. After the harvest of rice, wheat is grown as a winter crop on about 20-40 percent of the area. Figure 3 presents the cropping pattern and cropping intensity of the bari and khet lands of the Tinau Watershed Project area.

FIG.3

Trees and shrubs are grown usually in strips of 1.5 to 6 m width along the boundaries of the fields, and the strips are spaced about 25-30 m apart. Thus there are about 400 running metres of tree strips of varying width per hectare, covering roughly 10 percent of the land area (Fig. 4).

FIG.4

3.5. Interactions Between Components

The intimate association between the components of the system results in interactions, both positive and negative, in both space and time. The direct interactions involve those between tree strips and field crops (soil conservation, shading by trees on adjacent rows of crops), fodder trees and animals, cattle (manure) and crops, etc. One of the main competitive interactions is the use of grass for thatching vs for cattle feed. Then there are cyclic interactions involving the use of crop residues for soil protection and fertility build-up. But the most significant interaction effect between trees and crops in the system is that the whole system of farming on these hills with slopes up to 40 percent works only due to the existence of contour strips of trees and shrubs. These not only protect the soil from erosion, but also provide the much-needed fodder, firewood, and fence posts and other types of farm timber. The farmers are very aware

and appreciative of these positive interaction effects of the woody perennial strips so that they reconcile to the negative interaction effects (shading and consequently lower yields of crops near the trees, damage to young crops by dripping of large drops of rain from the overstorey trees, etc.).

4. SYSTEM FUNCTIONING AND DYNAMICS

4.1. Socio-Economic Aspects

Some of the basic farm management data are given below:

- average number of members per farm household: 6.4 (2-10), of which 2.8 are below 15 years of age

- land available per household:

private agricultural land:	crops 0.60 ha) grass 0.15 ha)	0.75 ha
private tree strips		0.09 ha
common grazing land		0.15 ha
forests (communal, governmental)		0.55 ha

- yearly labour input per household: 900 man days (m.d.)

for agriculture	450 m.d.
for animals	150 m.d.
for water and firewood collection, food preparation etc. unknown but steadily increasing; estimated	300 m.d.

- manure produced by stall-fed animals, equivalent to 35 kg N ha^{-1} yr^{-1}, is distributed on the fields;

- no chemical fertilizers;

- no other external inputs.

Usually all farm production is for home consumption only. The market facilities are poor; the quality of the produces is also poor compared to that of the products from the terai flatlands. Therefore, there is practically no sale of produce outside the village.

Usually all able-bodied persons work on the household farm especially at times of peak labour requirement such as sowing season. Moreover, it is also a common practice for the neighbouring families to help mutually in farm operations. All work requiring hard physical labour is done by men. During winter when there are practically no agricultural operations on the farm, there is a considerable extent of unemployment, when some men look for out-of-the-farm jobs.

About 10 percent of the households earn money by non-farming occupations such as carpentry, tailoring, handicrafts, etc.

4.2. Production

4.2.1. Agricultural Crops

The average yields of agricultural crops are:

Maize	899 kg/ha
wheat	637 kg/ha
millet	206 kg/ha
rapeseed	186 kg/ha

At an average of 6.4 members per family, these figures amount to an annual average of 90.9 kg of cereal grain production per capita. The average consumption of cereals per capita is 130 kg/year; thus there is a deficit of about 40 kg cereal grain per capita annually. This deficit is covered mainly by rice produced in the plains and foothills, which is purchased by cash obtained from the sale of animals or accrued by way of wages when the farmer works elsewhere as a paid labourer.

4.2.2. Fodder

TABLE 2

Table 2 indicates the fooder supply and demand position in the two villages of the study area. The Table indicates that the total production is less than the total demand. The deficit is met mainly by collecting fodder from distant areas. But it is also common that the animals are under-fed during the dry season.

4.2.3. Firewood

Each family farm has about 300 running metres of tree strips with 300-400 trees on them According to the farmers interviewed, these trees provide firewood for the family for about 4 months of the year. This figure sounds reasonable if we assume a mean annual consumption of 0.7 m^3 of firewood per head, and an average extraction rate of 17 m^3 ha^{-1} yr^{-1}. For the rest of the year, firewood is collected from the public forests around. However, since the growth rate in the public forests is very low (about 3 m^3 ha^{-1} yr^{-1}), these public forests are subjected to rapid degradation and overexploitation as can be seen from their depleted appearance all over the country.

4.2.4. Other farm products

A few poles and timber needed to build and maintain houses and for other farm uses are easily obtained from the trees on the contour strips. Some 10 percent of the families keep honey bees in log hives producing small amounts of honey and wax, which are used for household consumption only.

4.3. System Dynamics

From the foregoing descriptions, it is evident that this is a purely subsistence system on which practically no improvement has been made over the past several decades. It is likely to break down fast because of pressures of

population increase and a myriad of consequent problems - such as fragmentation of holdings, extending farming to marginal areas and forests causing more soil erosion and greater firewood shortage, overgrazing of pastures, decline in soil fertility and crop production level and so on and so forth. In short, the weight of all these factors is destroying the very basis of the improvements in land use. Even now, many people from the hills are migrating to the terai flat lands where new land suitable for agriculture is still available. However, this possibility will run out soon.

4.4. Overall Performance Assessment

This low-input, integrated production system has been functioning for quite some time, though at low production levels, primarily because of the existence of the horizontal contour strips of trees. The greatest contribution of these trees is their protective function in reducing the erosion hazards and thereby making crop production possible in those steep slopes where farming would otherwise be impossible without having extremely expensive and therefore unaffordable terraces and other physical measures of soil conservation. However, it has to be emphasized that these tree strips cannot often stop the erosion completely, but would only reduce the magnitude of erosion and/or improve the efficacy of the physical soil conservation devices.

The rainfall distribution pattern is so unsatisfactory that much of the total annual rainfall, which is reasonably high in several places, is received in a short span of time from July to September. This not only aggravates soil erosion, but also makes crop growth impossible without irrigation during eight months of a year.

The hill farming system is a thoroughly neglected system. Although it extends over quite a large area

and accounts for the sustenance of a large number of Nepal's population, it has not received any scientific research attention worth mentioning. As a result the system has continued without any positive change or technological innovations for the past several decades, and the poor farmers continued to become poorer and poorer as their numbers kept on increasing.

The important element of the system that can be extrapolated to other areas with similar problems is the use of multipurpose trees on such steep areas for erosion control and production of multiple outputs. Areas that are rated as unsuitable for sustainable crop production because of erosion problems will increasingly be brought under the plough to cope with the increasing population pressure, and then systems like this could serve as field examples where the concept of integrated agroforestry systems have been translated into practical possibilities.

5. IMPROVEMENT POSSIBILITIES

Two sets of possibilities can be visualized for the improvement of this system. First, the improvement through component technologies and secondly innovations in farming systems.

5.1. Component Technologies

A significant sign of improvement that has become evident in the recent past is that young, literate farmers -- majority of the older farmers are illiterate -- have begun to be interested in better inputs such as improved crop varieties, improved breed of cattle, better fruit trees and vegetables for marketing, use of fertilizers, etc., and these efforts have shown substantial improvement possibilities. Several arms of the extension machinery of His Majesty's Government of Nepal are now working in the area. These include agricultural development officers, livestock and veterinary officers, forest officers, agricultural development bank that gives credit facilities

on favourable terms, and so on.

5.2. Improved Farming Systems

Elements of improved farming systems will include use of more fruit trees and incorporation of a variety of multipurpose trees in the contour tree strips. Apiculture also has a good potential in the area. Intercropping of medicinal plants with the tree species also seems to offer a viable possibility especially in areas that are very unsuitable for food crop production. The special report "Medicinal Plants of Nepal" commissioned by the Food and Agriculture Organization (FAO) of the United Nations (Malla, 1982) gives a good account of the medicinal plants, their uses, availability and potential role in farming systems and community forestry programmes. Some of these medicinal plants have already been mentioned as components of the farming system of the study area (Table 1).

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Table 1 : Perennial plants in contour strips on farmlands in Western Nepal in the order of their occurrence.

Local name	botanical name	type	main use
Kutmero	*Litsea polyantha*	tree	fodder, fuel (timber)
Dabdabe	*Garuga pinnata*	tree	fodder, fuel (timber)
Keraa(banana)	*Musa* spp.	tree	fruit, mulch
Berulo	*Ficus clavata*	shrub	fodder
Chilaune	*Schima wallichii*	tree	fodder, fuel, timber
Kanyu	*Ficus semicordata*	tree	fodder, fuel
Assuro	*Adhatoda vasica*	shrub	live fence, erosion control
Sal	*Shorea robusta*	tree	timber, fodder, fuel
Gidari	*Premna spp.*	small tree	fodder
Badahar	*Artocarpus lakoocha*	tree	fodder, fruit, fuel
Bans	*Dendrocalamus strictus*	tree	fodder, fuel, timber
	Arundinaria spp.	tree	fodder, fuel, timber
	Bambusa spp.	tree	fodder, fuel, timber
Fosro	*Grewia* spp.	tree	fodder, fuel
Thotne	*Ficus hispida*	tree	fodder, fuel
Bilaune	*Maesa chisia*	tree	fodder, fuel
Khirro	*Wrightia antidysenterica*	small tree	live fence
Mayel	*Pyrus pashia*	small tree	fuel, timber, live fence
Koiralo	*Bauhinia variegata*	tree	fodder, fuel, fruit
Aap (mango)	*Mangifera indica*	tree	fruit, fuel
Boklimho	*Rhus javanica*	tree	fodder, fuel
Belaunti (amba)	*Psidium guajava*	tree	fruit, fuel
Arhu	*Prunus persica*	tree	fodder, fuel
Rohini	*Mallotus phillippinensis*	tree	fodder, fuel
simal	*Salmalia malabarica*	tree	fuel, timber, spice
Kaulo	*Machilus gamblei*	tree	fodder, fuel
Dhalai	*Castanopsis indica*	tree	fodder, fuel, timber
Gaelo	*Callicarpa arborea*	tree	fodder, fuel
Kiloa	*Tinospora malabarica*	small tree	fuel
Dalchini	*Cinnamon* spp.	tree	spice, fuel
Anghero	*Pavetta indica*	small tree	fuel
Paingyo	*Prunus cerastoides*	tree	fodder, fuel, timber
Amilo	*Berchemia floribunda*	tree	fruit, fuel
Khamari	*Gmelina arborea*	small tree	fodder, fuel
Kimbu	*Morus alba*	tree	fodder, fruit, fuel
Bakaino	*Melia azedarach*	tree	fuel, fodder
Kabro	*Ficus lacor*	tree	fodder, fuel
Darim	*Punica granatum*	tree	fodder, fuel
Gajyo	*Bridelia retusa*	tree	fodder, fuel
Amaro	*Antidesma diandrum*	shrub	fuel
Jamun	*Syzigium* spp.	tree	fodder, fuel
Lankuri	*Fraxinus floribunda*	tree	fuel, timber
Ankhatarvwa	*Trichilia connaroides*	tree	fodder, fuel
Chuletro	*Brassaiopsis hainla*	tree	fodder, fuel
Naspati	*Pyrus serotina*	tree	fruit, fodder, fuel
Barahmas	*Nerium odorum*	small tree	fuel, sacrificial value
Bharlo	*Bauhinia vahlii*	tree	fodder, fuel
Khari	*Celtis australis*	tree	fodder, fuel, timber
Aaru bakhadaa	*Prunus domestica*	tree	fruit, fuel
Balayo	*Rhus succedanea*	tree	fodder, fuel
Phaledo	*Erythrina variegata*	tree	fodder, fuel
Chiuri	*Bassia butyracea*	tree	fodder, fruit
Nemaro	*Ficus roxburghii*	tree	fodder, fuel
Bohori	*Ziziphus jujuba*	tree	fodder, fruit
Kafal	*Morus indica*	small tree	fruit, fuel

TABLE 2

ANNUAL PRODUCTION AND DEMAND
OF FODDER IN THE TWO VILLAGES
OF THE STUDY AREA

	Village 1		Village 2	
	tons TDN*	% of total demand	tons TDN*	% of total demand
PRODUCTION				
Agricultural by-products - wheat) - maize) - millet) - other)	28.8	14	13.2	7
Privately owned trees (contour strips)	85.9	41	101.6	58
Private grassland	3.0	1	4.2	2
Forests (government, communal)	49.6	23	43.6	25
Common grazing land	5.7	3	6.3	4
Total	173.0	82	168.9	96
TOTAL DEMAND	211.4	100	176.7	100
TOTAL DEFICIT	38.4	18	7.1	4

* TDN = Total Digestible Nutrients

Basis of calculation

BLU - Big Livestock Unit of 300-400 kg live weight
1 cattle - 0.80645 BLU
1 buffalo - 0.86666 BLU
1 goat/sheep - 0.06 BLU

For Nepal, an annual fodder demand of 2t dry matter/BLU equivalent to 1t TDN/BLU is estimated

Source : Pandey (1982).

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FONZEN & OBERHOLZER
HILL FARMING IN
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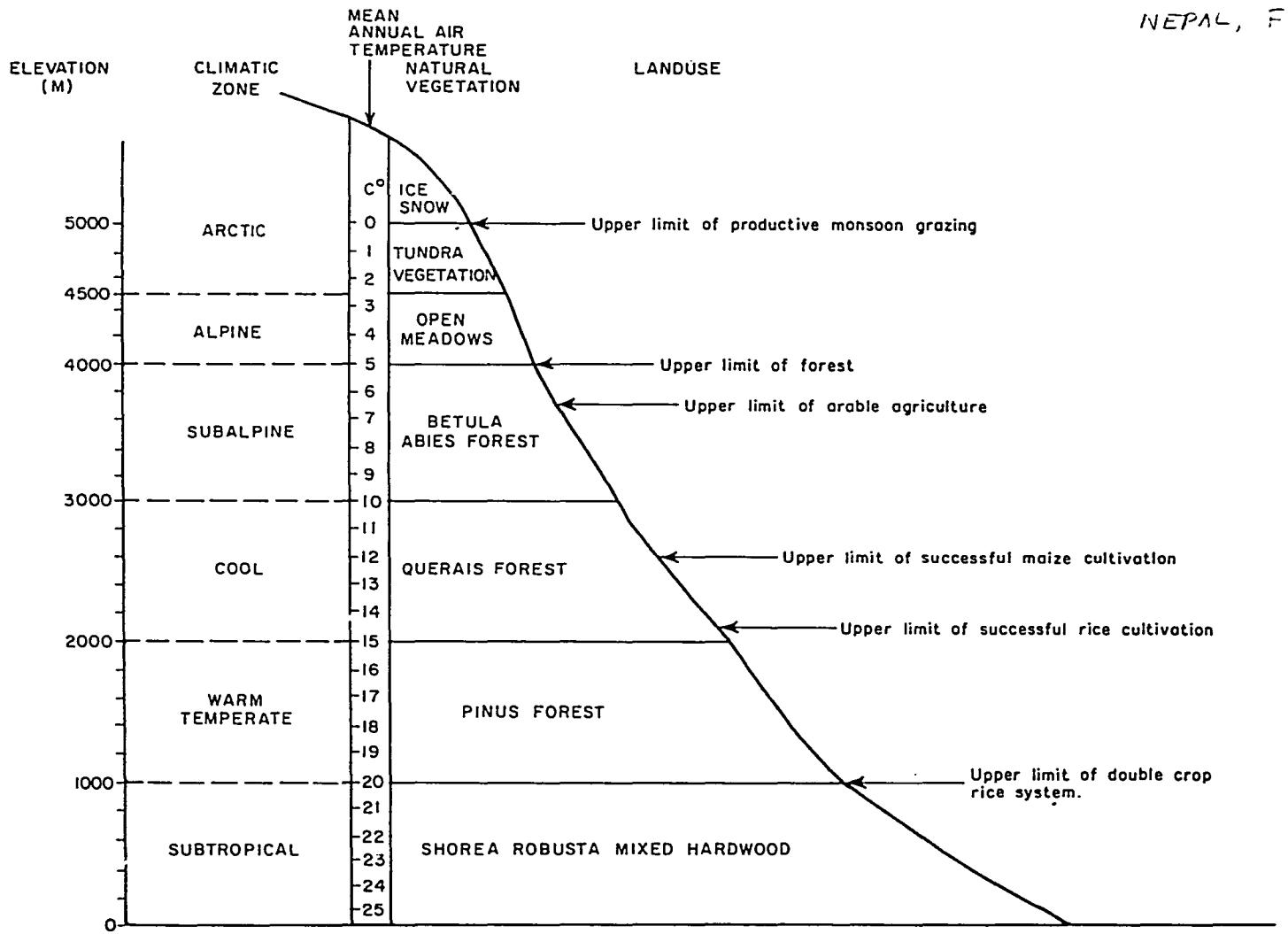

LONZEN & ÖBERHOLZER
AF SYSTEM DESCRIPTION Nº 4
HILL FARMING IN NEPAL

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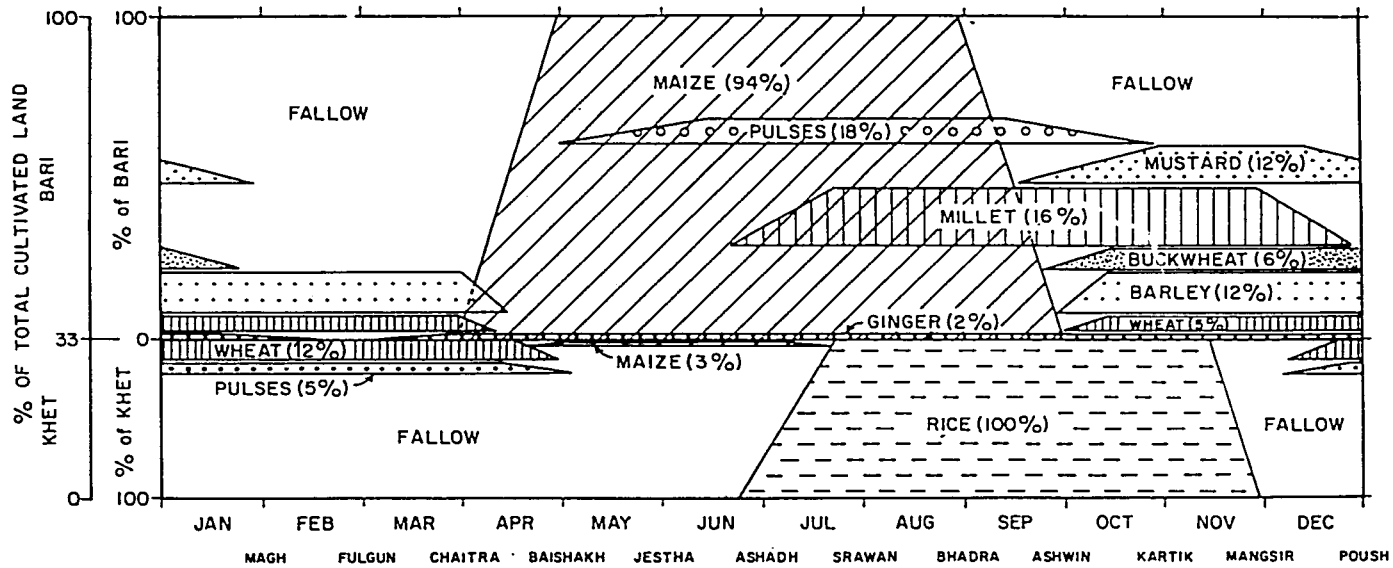

Annex 14

PARAISO (*MELIA AZEDARACH* VAR. "GIGANTE") WOODLOTS: AN AGROFORESTRY ALTERNATIVE FOR THE SMALL FARMER IN PARAGUAY.

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PARAISO (MELIA AZADARACH VAR. "GIGANTE") WOODLOTS: AN AGROFORESTRY ALTERNATIVE FOR THE SMALL FARMER IN PARAGUAY

by

P.T. EVANS AND J.S. ROMBOLD

ABSTRACT

This paper describes the salient aspects and analyses the potential of the "Paraiso Woodlot" System, which is becoming popular as an agroforestry alternative to land use in the degraded acid sandy soils of the humid sub-tropical Guayaybi area of Paraguay. The system consists of a combination of paraiso *(Melia azedarach* var "gigante") with other trees, especially *Leucaena leucocephala,* and annual crops.

The fast growth habit, deep root system, addition of large quantities of organic matter through leaf and litter fall, compatibility with agricultural crops, high value of the sawlogs and production of substantial quantities of poles and firewood make paraiso an excellent species for agroforestry combination. Preliminary results of the trials indicate that the "woodlots" are successful and with increasing efforts of the extension agencies, they are being accepted as a viable alternative to traditional agricultural systems.

Besides discussing the potential of these "woodlots" based on initial results, the paper identifies the constraints of the system and highlights the priority research areas.

Key words:

Agroforestry, Farm woodlots, Leucaena, Paraguay, Paraiso *(Melia azedarach)*

1. INTRODUCTION

The Paraguayan Agroforestry Extension Project is a cooperative effort between Paraguayan national agencies and international technical assistance organizations. Initiated in June 1981, the project aims to better address the problems of rural farmers in Paraguay, by introducing new, more sustainable systems of land culture.

The most promising system developed by the project is a mix of "paraiso" (*Melia azedarach* var. "gigante") with other trees and annual crops and is popularly known as "paraiso woodlots". Where well-tended, the paraiso woodlots have performed with excellent results. With increasing popular acceptance through the efforts of the extension agencies, the woodlots seem to be establishing themselves as a viable alternative to traditional agricultural practices. This paper describes the salient aspects and projects the potential of paraiso woodlots as an agroforestry alternative to land use in Paraguay.

2. GENERAL DESCRIPTION OF THE AREA

2.1. Geographical Location

The longest established paraiso woodlots are located in the Department of San Pedro, in the locality of the town of Guayaybi (24° S latitude, 56° W longitude). This area was first settled 20 years ago by small farmers moving from older, more crowded regions. With no electricity, running water or paved roads, Guayaybi remains a simple, undeveloped area.

2.2. Biophyshical Environment

Guayaybi lies within the Paraguay River watershed. The topography is gently rolling, with almost flat valleys drained by slow-moving rivers.

The average elevation ranges between 200 and 250 m.

2.2.1. Climate

Guayaybi has a humid, sub-tropical climate. The annual rainfall averages 1500 mm and is well-distributed throughout the year. Much of the precipitation occurs as intense downpours. The yearly temperatures in the area average 24^{0} C. Frosts are variable; some years are frost-free and others have several or more light freezes, the average being two frosts a year.

2.2.2. Soils

The soils in the area are sandy red-yellow podzols derived from Triassic and upper Permian red sandstones. Most of the soils are acidic sandy loams with a variable clay fraction and pH in the range of 4.2 to 6.5. Soils of the areas that have been cleared for agriculture are more acidic, have a lower percent organic matter content and are more extensively leached than corresponding soils under forest cover. Bedrock is encountered at depths of 15-25 m.

2.2.3. Vegetation

A tall, humid, semi-deciduous forest forms the climax vegetation of the Guayaybi area. This forest contains many hardwoods highly valued for their quality lumber. Scattered emergent trees, such as tajy *(Tabebuia ipe)*, yvyra-pyta *(Peltophorum dubium)* and kurupay-kuru *(Anadenathera macrocarpa)* rise above a layer of co-dominant species, characterized by guatambu *(Balfourdendron riedelianum)*, laurel *(Ocotea* spp.) and yvyra-pepe *(Holocalyx balansae)*. The understory is dense and woody.

2.3. Landuse Systems

2.3.1. Agriculture

The lands around Guayaybi are owned by small farmers. Most of the farms in the area are 10-20 ha in size. The farmers practice agriculture at a rudimentary level. They cultivate maize *(Zea mays)*, groundnut or peanuts *(Arachis hypogea)*, cassava *(Manihot escultenta)*, beans *(Phaseolus vulgaris)* and bananas *(Musa* spp.) for their own consumption or to sell locally. In addition, cotton and tobacco are planted as cash crops for export. The families depend greatly, but not entirely, upon their farms for subsistence. Sour orange *(Citrus aurantium)* is grown in plantations for a fragrant oil used in perfumery.

Typically a form of slash-and-burn agriculture is used. To start, forested land is divided into lots. Each farmer periodically clears a portion of his lot and plants cotton or tobacco as the first crop on the new land. These crops grow well for 2-4 years; thereafter their yields decline sharply. Subsistence crops are then planted on such "old land" and more forest is cleared to plant cash crops. Eventually when the cash crops will have to be planted on the leached, nutrient-depleted soils which had long since had their forest cover removed, the farmer either sells his land at a low price and moves to a new area, or stays, faced with the prospect of steadily dwindling crop yields.

Each family has a small number of pigs, cattle and chickens. Pigs are fed table scraps and allowed to root in the fields. Cattle are crowded on small over-used pastures. They gain weight slowly on forages high in roughage, low in protein and insufficient in quantity. Milk yields are low. Chickens yield small amounts of meat and eggs. They graze

around the houses and occasionally are thrown some corn, but are otherwise left uncared for.

2.3.2. Forestry

Thirty percent of the Guayaybi area is covered with natural forests, the rest having been cleared for agriculture. In the 1960's this forest was selectively cut. The valuable species, such as tajy *(Tabebuia ipe)*, peterevy *(Cordia trichotoma)*, yvyara-ro *(Pterogyne nitens)* and cedro *(Cedrela tubiflora)* were removed. The remaining forest contains species for which there is little or no market outside local use. For this reason the cut-over forest is not valued. There are few industries based on wood products from the natural forest in Guayaybi.

3. STRUCTURE OF THE PARAISO WOODLOT SYSTEM

Drops in productivity to as little as a half to a third of what was harvested previously indicate agriculture, as currently practised in the area, is not sustainable in the long term. This drop in productivity is primarily due to soil and climatic conditions that predispose the land to fertility loss after deforestation:

- the sandy soil is readily leached;
- organic matter, abundant in the natural forest soils, diminishes rapidly after forest clearing;
- intense, erosion-causing rains are common; erosion losses range from 30 to 100 t ha^{-1} of soil or even more.

In an effort to rebuild soil fertility and use their degraded lands farmers are turning towards agroforestry (paraiso woodlots) as a land use alternative.

3.1. Components

3.1.1. Crops

Common subsistence crops grown in the woodlots include bananas *(Musa* spp.), beans *(Phaseolus vulgaris)*, cassava *(Manihot esculenta)*, maize *(Zea mays)* and groundut *(Arachis hypogea)*. Vegetable crops for urban markets are also sometimes grown, such as onion *(Allium cepa)*, bell pepper *(Capsicium annum)*, tomato *(Lycopersicon esculentum)* and watermelon *(Citrullus vulgaris)*.

Crop management consists primarily of weeding with a hoe. Two crops are grown each year: one in early summer and another in the fall. Groundnut, pepper, tomato, onion and watermelon are early crops. Maize, beans and cassava are grown year-round except in the cold monts (June-August). Beans are often grown in combination with cassava and/or maize.

3.1.2. Trees

Paraiso *(Melia azedarach* var. "gigante") is the main tree component of the system. It is a fast-growing exotic with an erect growth form. Little shade is cast by the crown. Paraiso produces an attractive wood that can be used in furniture making, plywood, veneers and interior carpentry.

- Planting. Paraiso is planted as a bare-root stump. The planting site should be freshly ploughed. A crop is planted between the tree rows and the trees are kept weed-free through the periodic weedings done for the crop.
- Pruning. The tree require pruning for the first two years, enough time to develop a limb-free 6 m bole.

- Thinning. Paraiso is shade-intolerant and should be maintained at low densities for fast growth. At a 4 x 3 m spacing at least two thinning will be required: first in year 5, and next in year 8, 50 percent of the trees being removed with each thinning.

- Harvest. In 12 years, 200 trees will be ready for harvest, with an average DBH of 40 cm. All the trees may be harvested at this time, or 50 percent may be removed and the remaining trees harveste in year 15, with an average DBH of 50 cm.

Leucaena *(Leucaena leucocephala* var. K-67, K-28 and Cunningham) is also planted to produce forage, firewood, posts and poles. Leucaena has failed to nodulate in the Guayaybi area, probably due to high soil acidity. Nonetheless, it grows well.

- Planting. Leucaena is planted as a bare-root stump, either inter-mixed with paraiso or in separate rows.

- Pruning. If the Leucaena is to be used as posts or poles it is pruned for the first 4 years. If it is to be used as forage the top is cut-off periodically at 1.5 m.

- Harvest. The Leucaena is harvested on an as-needed basis for firewood, posts and poles.

Peterevy *(Cordia trichotoma)*, timbó *(Enterolobium contortisiliquum)*, yvyra-ro *(Pterogyne nitens)* and yvya-pyta *(Peltophorum dubium)* are native hardwoods valued for their high quality lumber. Timbó and yvya-pyta fix nitrogen and are good soil improvers. All produce posts and firewood as secondary products.

- Planting. Plant as bare-root stumps, either intermixed with the paraiso or in separate rows.
- Pruning. The native species (with the exception of peterevy) grow with poor form. Constant pruning is required to insure the formation of a single trunk. The paraiso overstory, once formed, will shade the native hardwoods, inducing superior growth form (but slower growth).
- Thinning. Trees with poor form or slow growth should be thinned out.
- Harvest. The native species should be of harvestable size (40 cm) in 25-35 years.

Yerba maté *(Ilex paraguariensis)* is a small, shade-tolerant evergreen tree. The leaves and small branches are dried, ground-up and used to make a mildly stimulating tea (tereré, the national drink).

- Planting. Yerba maté should be raised in containers and planted during winter one year after the paraiso has been established.
- Harvest. After 5 years of growth yerba maté is ready for its first harvest. The foliage and twigs are cut, leaving the trunk and larger branches. Trees are harvested once every two years and harvest continues for about 30 years.

3.1.3. Animals

On an average, each farm supports an average of six heads of cattle. Of these, two are oxen used to work the fields and haul the produce to market; two are milk cows; and the remaining two are young animals. The cattle -- unimproved crosses between zebu-type and

European breeds -- are not good producers of meat or milk, but are resistant to the diseases and are adaptable to the local climate.

3.2. Arrangement of Components

The arrangement of the woodlot components is flexible; it varies according to the needs of the farmer. Two combinations will be explained in detail:

3.2.1. Paraiso with yerba maté and bananas

- Year 1. Paraiso is planted at 4 x 3 m spacing. At the same time 4 rows of groundnut are planted between the paraiso rows, to be followed by beans.
- Years 2-4. Yerba maté is planted in the paraiso rows in the second year at 3 m spacing. Maize, beans and cassava are planted between the tree rows.
- Years 5-14. One row of bananas is planted in the fifth year with 3 m between each banana plant. Paraiso can be cut in year 1.
- Year 15. Final harvest of paraiso for sawlogs.

FIGURE 1A
FIGURE 1B

Schematic presentations of this arrangement in years 1 and 7 are given as Fig. 1a and 1b.

3.2.2. Paraiso with Leucaena and Timbó

- Year 1. Rows of paraiso are planted 3 m apart from rows of Leucaena (var. K-67) mixed with timbo. Trees within the paraiso rows are spaced 3 m apart, trees in the Leucaena rows are spaced 2 m apart. Three rows of groundnut are planted between the trees, to be followed by beans.

- Years 2-3. Maize, beans and cassava are planted between the trees.
- Years 4-14. Grass is planted and 2 heads of cattle/ha are allowed to graze the woodlot. The Leucaena is harvested as needed for forage, posts, firewood and poles. Harvest of paraiso for sawlogs can be started in year 12.
- Year 15. Final harvest of paraiso for sawlogs. The primary component of the woodlot is now timbó.

FIGURE 2A
FIGURE 2B

Figures 2a and 2b show the schematic pattern of this combination in years 1 and 7.

3.3. Interaction of Components

The most readily observable interaction is competition for light between:

- Trees and weeds. Paraiso's growth is stunted when weed competition is intense. Growth is more than double when a crop is planted between the tree rows and the field is kept free of weeds.
- Trees and crops. In the first year, a tall, fast-growing crop such as maize will shade the paraiso and slow its growth. Later, when the trees are taller, the opposite occurs and it becomes no longer possible to plant sun-loving crops.
- Trees and trees. If allowed to become too dense, paraiso's growth is slowed. Likewise, without periodic thinnings of the paraiso overstory, little light reaches the intermediate layer of leucaena and native hardwoods (if these components were included).

Thus, it is important to carefully plan spacings and thinnings to optimize the performance of the system's components.

Another important interaction is the amelioration of the environment by the tree overstory. Frosts, high winds and intense solar radiation are mitigated to some extent by the crowns:

- the partially shaded bananas have a lower incidence of sigatoka *(Cercospora musae)* disease;
- under shade, yerba maté grows better than when in full sunlight;
- cattle grazing beneath the overstory are less stressed by heat;
- crops (melon, tomato, pepper, etc.) interplanted with trees are protected from late frosts and can be planted earlier.

Other interactions include the production of forage for cattle and of nectar for bees (if a bee component is included).

4. SYSTEM FUNCTIONING

4.1. Resource Input and Utilization

4.1.1. Land

The size of the paraiso woodlots ranges between 0.25 and 2.0 hectares, with and average of about 1.0 ha. Thirty seven families in the Guayaybi area have planted woodlots in a land area of about 35 hectares. These families have bought lands from the government and are full owners of their farms. The average population density is 0.7 persons/ha. This population density is currently increasing, due to immigration from older areas and a high birthrate (4.1%). In the future it is expected there will be a diminution of farm size from the current average of 12 ha/family to about 7 ha/family as land holdings are subdivided.

4.1.2. Capital

Only a small capital expenditure is required. Trees are sold at 10 guaranies (100 guaranies = $0.30 U.S. dollars in March 1984) a piece. All technical assistance provided by the project is free.

4.1.3. Labour

The largest investment is the labour required to establish and maintain the plantation. To plant one hectare, the following labour inputs (mandays) are required: ploughing - 2; tree planting - 2; sowing of crops - 1; weeding/hoeing (four times) - 16; pruning - 2 days the first year and 3 the second year.

4.2. Pattern

In Paraguay agroforestry activities are best undertaken during the cool months (May-September). During this period there is little work to be done in the fields. Also, during the winter, trees experience less stress after transplanting. From October to April the farmers are busy planting, tending and harvesting their cotton and tobacco crops.

Seeds are collected inside the country and are distributed free to the agroforestry extension nurseries. Trees from these nurseries are then sold at a low price to interested farmers. All traction power is supplied by oxen. Pesticides are sometimes used on vegetable crops intended for the market. Fertilizers are not used because of their high cost and limited availability.

4.3. Production

Though no accurate data is available on the yields of agricultural commodities from the paraiso woodlots, estimates indicate that a paraiso

woodlot (4 x 3 m spacing), underplanted with bananas and yerba maté, will have produced 4 m^3 ha^{-1} of posts, poles and firewood and 176 m^3 ha^{-1} of sawlogs by year 15. A woodlot of paraiso (3 x 6 m spacing) mixed with Leucaena and native species, will have produced, by year 15, 75 m^3 ha^{-1} of posts, poles and firewood from Leucaena and native trees and 176 m^3 ha^{-1} of paraiso sawlogs. Preliminary data on the growth of paraiso and Leucaena in the Guayaybi area are given in Table 1. Photographs of the 6 month- and 12 month-old trees are given as Fig. 3a and 3b.

TABLE 1

FIGURE 3A

FIGURE 3B

Initially the primary output of the woodlots is food crops. As the trees grow taller the emphasis is shifted to shade tolerant crops (banana, cassava) and wood products. The sawlogs are grown for the local market and/or export. The other outputs are intended for home consumption.

4.4. Protective and Service Aspects of the System

One of the primary goals of the woodlots is the improvement and productive utilization of degraded soils. Most farms more than 10 years old (after first forest clearing) have fields that are either producing very little or have been taken out of production altogether. The paraiso woodlots have potential to improve soil in the following ways:

- organic matter is added to the soil through leaf drop and root decomposition;
- nitrogen is added to the soil by nitrogen-fixing trees included in the woodlot;
- aeration of the soil through the action of tree roots;
- retrieval by deep tree roots of nutrients leached below the root zone of annual crops;
- prevention of further soil erosion and subsequent fertility loss by the formation of a permanent protective vegetative covering.

The paraiso woodlots are re-vegetating and utilizing formerly unproductive farmlands. The quantative effect of the woodlots on soil quality is not yet known. However, qualitatively it can be observed that humus layers are being rebuilt and that soil structure is becoming less compact and more porous where woodlots have been planted.

4.5. Socio-Economic Description

In rural Paraguay, incomes ebb and flow with the tobacco and cotton harvest. Little income is realized from the sale of other crops. From October until January farmers spend large amounts of capital on seed and pesticides. By harvest time most families owe money to local merchants for food, clothing, tools and agricultural products. If the price for cotton and tobacco is good, the farmers earn enough profit (average harvest income from 2 ha of cotton = U.S. $ 800) to pay off their debts and buy needed items. Often though, the price of cotton is low and families have problems meeting their debt obligations. These are the times of greatest emigration out of the rural areas, as the less-successful farmers sell their lands and seek work in urban centers.

The paraiso woodlots add a long-term dimension to the economic outlook of the rural farmer. The system has a real potential to provide large amounts of income 10-15 years after planting. The value of the harvested sawlogs has not been established on the Paraguayan market. However, in Argentina paraiso is replacing cedro *(Cedrela tubiflora)* -- one of the highest priced native hardwoods -- on the market, largely because the supplies of cedro are almost exhausted. Based on this, the value of a mature paraiso woodlot is estimated to be U.S. $ 5100-6800 per hectare. The prospect of this long-term profit adds security to families'

futures and encourages them to view agriculture as a long-term, sustainable enterprise.

4.6. Overall Performance Assessment

Paraiso has demonstrated its potential as a fast-growing reforestation species. When degraded land units with the woodlots are compared to similar land units without the trees, the advantages become obvious: formerly unproductive units of land are now supporting fast-growing trees and crops and are directly adding to the well-being of the families who work the land.

5. SYSTEM DYNAMICS

5.1. Rate of Growth

The paraiso woodlots are a new landuse alternative and are expanding at an impressive rate. The demand for trees to plant woodlots is outstripping the production capabilities of the extension nurseries. According to an FAO study, Paraguay's wood products industry has 15 years of life left before it runs out of reserves of commercially valuable species. Paraguay's forests are being destroyed at the rate of 3.3 percent each year, the fastest deforestation rate in the Western Hemisphere. At the same time, the demand for Paraguayan wood products is projected to be 14 times greater in the year 2000 than its former level in 1970. On top of this, Paraguay has a high population grwoth rate and limited arable land. These factors add impetus to the push towards sustainable systems that produce both wood products and food, such as the paraiso woodlots.

5.2. Degradation of the System

The first two years of the woodlot are critical. The trees must be kept free of weed competition or their growth is stunted. This is the stage where the extensionist has a key role. Farmers who have been well-supported by a forest extensionist have confidence in the woodlot and are willing to work hard to keep the trees free of weeds. Other farmers who have had weak support often develop doubts, concentrate their labour elsewhere and let the weeds grow, choking out the trees. It has been observed many times that when a woodlot fails, it happened because the farmer believed it would fail and did not invest the necessary labour.

5.3. System Sustainability

Since the paraiso woodlots are new, no data is available at this time on their sustainability.

6. EVALUATION

6 Merits

1. Paraiso grows rapidly, quickly establishing a vegetative cover and producing wood products in a short time (see Table 1).
2. The woodlots effectively combine food crops and trees to provide products for home consumption and the market on priorly unproductive lands.
3. The system shows promise as a means of rehabilitating degraded soils and protecting against erosion.
4. A prospect for long term stability and security is gained by the farmers who plant the woodlots.

6.2. Weaknesses

1. Biological. In some plantations paraiso has been attacked by an unknown pest or disease. The attacked trees develop a horse-tail shaped brooming of the growing tip. Apical dominance is lost and the trees cease active height growth. Up to 10 percent of the trees in some plantations have been attacked. Leaf-cutter ants are another major pest, sometimes causing complete defoliation.

2. Climatic. In the sapling stage paraiso is susceptible to frost damage.

3. Edaphic. When used as a component of a woodlot, Leucaena has exhibited little tendency to nodulate on acid (pH $\leq$ 5.0) soils. Nevertheless, it grows rapidly.

4. Ecological. Paraiso does not compete well with weeds.

5. Technical support. Paraiso woodlots are a new landuse method that farmers are unfamiliar with. To be successful, the farmers need strong technical support from well-trained extensionists. Due to institutional constraints, this support is often difficult to provide.

6.3. Constraints

The lack of strong governmental support for an agroforestry programme is the primary constraint limiting the success of the paraiso woodlots. Without this support, it is difficult to provide the minimal level of technical assistance necessary to manage the woodlots. The spread of the woodlots in the field is outgrowing the institutional capabilities to support them.

Another constraint is the uncertain market for paraiso sawlogs. In Misiones, Argentina, a province along the southern border of Paraguay,

paraiso is the second major reforestation species (after eucalyptus), and there is an ample market for the sawlogs produced. A similar market could be developed for paraiso in Paraguay, but does not exist as yet.

6.4. Potential

With greater institutional support and a firm market, paraiso woodlots could become a common landuse in Paraguay. The woodlots could be made more productive by:

- using improved strains of pasture grasses;
- including an apicultural component if nectar-producing tree are planted in the woodlot;
- including more shade-tolerant crops, such as coffee, papaya, etc.;
- incorporating more nitrogen-fixing, soil-building leguminous trees other than Leucaena;
- collecting paraiso seed from superior trees and initiating a tree improvement programme.

6.5. Extrapolability

In Paraguay and Argentina, paraiso is cultivated on acidic clay and sandy soils, in climates ranging from warm temperate to subtropical, with precipitation between 1400 mm - 2000 mm. While extrapolable to areas with similar conditions, it is not known how the tree would grow in more tropical climates or at higher elevations.

6.6. Research needs

Through research, the paraiso woodlots and their management could be improved. Some research needs are:

- growth predictions for different site conditions;
- quantitative outputs of the crop component and how the tree component affects this yield;
- effects of *azedarachin*, a compound contained in paraiso leaves, on crop pests;
- growth rates of native species that could be used in the woodlots;
- effects of the woodlots on soil fertility over time;
- cost/benefit analysis of the woodlots;
- timing of thinning;
- pests and diseases of paraiso, focusing upon the horse-tail brooming and upon the relationship between root damage due to ploughing and root rot proliferation.

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Data/Information Base

The following persons may be contacted for more information regarding the paraiso woodlots:

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Table 1. Early Growth of Paraiso and Leucaena Woodlots in the Guayaybi Area

Woodlot	age (months)	Paraiso		Leucaena	
		mean height (m)	mean DBH (cm)	mean height (m)	meam DBH (cm)
Casere	9	3.34			
Acosta	6	2.98			
Soria	8	2.93		3.08	
Ronan	8	2.24		2.25	
Ortiz	12	3.76	3.32	3.22	2.50
Ortiz	19	7.00	5.75		

FOOD, COFFEE AND CASUARINA: AN AGROFORESTRY SYSTEM FROM THE PAPUA NEW GUINEA HIGHLANDS*

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FOOD, COFFEE AND CASUARINA: AN AGROFORESTRY SYSTEM FROM THE PAPUA NEW GUINEA HIGHLANDS

ABSTRACT

An agroforestry farming system is described from the Papua New Guinea highlands (1400 to 2100 metres) that has been developed by village growers since about 1960 and has expanded rapidly since about 1970. Major components of the system are numerous species of annual and perennial food crops (especially bananas), arabica coffee and *Casuarina oligodon*. It provides food, a cash crop and timber for construction and fuel. It is likely that returns on labour inputs are very favourable, but no formal assessments have been made. Evaluation of the system as a whole, and research on certain key components (casurarina ecology, banana cultivars, timing of operations) are suggested as high priority areas for systematic studies.

Keywords: Agroforestry, casuarina, coffee, food crops, highlands Papula New Guinea.

1. INTRODUCTION

Within the central highlands of Papua New Guinea (PNG) live just over a million people. Most of these are village dwellers whose major cash crop is Arabica coffee (*Coffea arabica*). These smallholders produce 70-75 percent of the nation's total production of coffee, which is the major export crop. The majority of new coffee plantings made by smallholders in recent years have been in agroforestry systems that incorporate annual and perennial food crops, coffee and shade species. One such system is described here.

2. GENERAL DESCRIPTION OF THE AREA

PNG has a land surface area of 464,000 km and is located between the equator and 12°S latitude and 141-156°E longitude. The dominant natural environments are mountains and foothills of less than 1000 m altitude to peaks at 4500 m. The central highlands consist of a complex association of mountains and intermountain valleys (1).

The nation lies wholly within the humid tropics and humidity is high everywhere. The main influence on temperatures is altitude and, away from the moderating influence of the ocean, there is a very close and linear relationship between temperatures and altitude. Madang with mean maximum and minimum temperatures of 30°C and 23°C is typical of coastal locations. Mount Hagen town (1700 m) is typical of locations in the intermontane valleys with a mean maximum and minimum temperature of 24°C and 13°C respectively. Seasonal temperature variations is everywhere small to negligible. Mean annual rainfall varies from 1000 mm to over 8000 mm, but most people live in locations which lie within the range of 1500 to 4000 mm. Many locations experience a drier period between May

and September, but there are variations on this including a reversal of this pattern in some localities.

Floristically rich and luxuriant rain forests cover over 75 percent of PNG's land area. The forest types are broadly categorized into five to six sections, based on altitude, floristic composition and physiognomy of the structural forms. They include various vegetation forms of lowland (coastal, mangrove, evergreen, etc.), montane, and subalpine types (7).

The system described here is practised over an estimated 25,000 ha in PNG highlands (4) at an altitudinal range of 1400 to 2100 m where the annual rainfall varies from 1900 to 5000 mm (mostly between 2000 and 2800 mm). The soils on which the system is practised are variable, but typically contain significant amounts of volcanic ash, are high to very high in organic matter (5 to 20%) and are often poorly drained.

Sweet potato *(Ipomoea batatas)* is the staple food of both the people and their most important animal, pigs. Numerous other species are grown as food crops, often in mixed vegetable gardens that do not include sweet potato. It is these mixed vegetable gardens that form the basis of a recently developed food crop/coffee/casuarina system. At these altitudes, firewood for cooking and household heating is an important part of the ecosystem. In many highland areas it is now a scarce resource.

3. STRUCTURE OF THE SYSTEM

The major species used in the system are numerous annual and perennial food crops, arabica coffee and *Casuarina oligodon*. *C. Oligodon* is a fast growing woody species that provides shade and timber for fencing

house construction and firewood. Its timber is easy to split and it burns well. The food crops include bananas *(Musa* cvs) (mostly triploid cultivars at these altitudes), taro *(Colocasia esculenta* and *Xanthosoma sagittifolium)*, sugarcane *(Saccharum officinarum)*, maize *(Zea mays)*, highland "pitpit" *(Setaria palmifolia, Amaranthus* spp., *Oenanthe javanica, Rungia klossii* and others. Other components which may be present are nut pandanus *(Pandanus jiulianettii)* at altitudes above 1800 metres and oil pandanus *(Pandanus conoideus)* below 1700 m. Pigs commonly graze under established coffee/casuarina/banana stands, but they are not a critical component of the system. Cassava *(Manihot esculenta)* is an important component of a similar system used on better drained soils, but not in this system on the wetter soils.

The basic structure of the system is that mixed vegetable gardens are gradually converted into coffee/banana gardens and eventually into coffee/casuarina stands. Figure 1 shows the establishment of casuarina and coffee mixed with food crops in an area where some mature casuarina trees are already existing. Figure 2 shows an established system with 3-4 year-old bearing coffee under the shade of triploid bananas and some casuarinas. Other agricultural crops are no longer cultivated at this stage.

FIGURE 1

FIGURE 2

4. SYSTEM FUNCTIONING

The first phase is that fallow vegetation is cleared, drains are established and all of the food crops are planted in the mixed vegetable garden. Most plantings are made seasonally towards the end of the drier months (September to December). Coffee seedlings may be transplanted into the garden when the food crops are planted, but usually they are not planted until the short term crops, such

as the leafy green vegetables, have been harvested. Casuarina seedlings are sometimes transplanted at the same time as coffee, but they may be established up to 12 months after coffee. Seedlings of coffee and casuarina are usually obtained from self-sown plants in older coffee gardens and along alluvial flats respectively. The food crops are planted in a mixed planting arrangement without regular spacing or species association. By contrast the coffee and casuarina seedlings are planted in a regular manner that approximates to the recommended spacing (1.5 x 2.5 m for coffee).

The timing of planting of the major components is extremely variable. Shading of young coffee is provided by different species during different periods. Initially it is done by the taller food crops, particularly maize, *Colocasia* taro and sugarcane. Once the bananas are established, they provide an increasing proportion of the coffee' shade needs. About a year after planting, they are the major shade species. After about 2 years, they are increasingly supplemented by the slower growing casuarina. Bananas and casuarina both provide shade up to about years 5-7, by which time casuarinas are replacing bananas. Depending on altitude, one or two *Pandanus* species may be significant components of the coffee/casuarina stand.

The major input is human labour. The major output of the system are the vegetables that supplement the sweet potato staple, the cash crop (coffee) and eventually timber from casuarina. Productivity and other details of the system are poorly documented.

5. SYSTEM DYNAMICS

Coffee was promoted as a village cash crop in the highland from the mid 1940s onwards. The official government recommendation was (and

still is by default) that short term shade trees *(Crotalaria micans, Tephrosia vogelii)* or permanent shade species *(Casuarina oligodon, Leucaena leucocephala* or *Albizia chinensis)* should be established prior to field plantings of coffee seedlings without any interplanting of food crops. The official system was used initially, but from about 1960 onwards the system described here and other similar ones that incorporated food crops were developed by the villagers themselves. Their systems have expanded, so that by the late 1970s, most new coffee plantings by villagers in the highlands were being established in systems similar to this one. The system described here is an extension of the traditional mixed vegetable garden system and it is the most widely practised of the recently developed integrated food/coffee/timber systems.

The overall performance of the system has not been quantified and hence not evaluated. Judging by the system's rapid expansion and widespread adoption, this system is more efficient than the officially promoted method of establishing coffee. Based on theoretical calculations of economic returns from integrated systems in comparison with the coffee/shade system, Carrad (4) concluded that the integrated one was very superior, especially from planting to year 7.

6. EVALUATION

This agroforestry system provides food, cash from coffee and some marketed food, and timber for construction and fuel. It has not been critically evaluated, but based on the author's judgement it is certain that returns on labour inputs would compare very favourably with alternative systems. Because the canopy is maintained continuously by a sequence of faster and slower growing species, the requirement for weeding is minimized.

The author does not see many major weaknesses of the system for small-holders. It is a conservation system in that the soil is protected from the direct action of the elements by continuous vegetable cover, and hence organic matter is conserved. Conversion of land suitable for mixed vegetable gardens into permanent coffee stands may be a problem in those few areas where this land type is limited in extent. Sometimes growers using the system fail to establish a good coffee stand. The reasons for this are not clear. A reasonable level of managerial ability is needed to manage the system, but this is within the capability of most village growers. The level of management may be more difficult to attain when larger plantings are being established in a limited time, for example areas larger than 3 ha.

The system provides significant quantities of perishable food. Because of poorly developed marketing infrastructure in PNG, marketing of this is likely to pose problems for larger growers.

Similar systems have been developed by villagers elsewhere in PNG for other export tree crops, including cacao (2), coconuts (5), rubber and oil palm. There is a wide variation in the details of this and other systems, especially in relation to timing of operations and species used for shade. It is very likely that some growers have refined the system; for example, selection of superior banana cultivars for shade or the timing of transplanting of coffee and casuarina seedlings. Such refinements are likely to have wider applications, at least within the PNG highlands and perhaps elsewhere. *Casuarina oligodon* is restricted to the highlands of the island of New Guinea where it grows between 650 m and 2700 m (standard deviations for the species's altitudinal limits are 60 m and 55 m respectively). Casuarina is known to fix

atmospheric nitrogen, although the amount is yet to be quantified. The species's useful characteristics and agroforestry potential are widely recognized within PNG (8) and it may have potential as a shade and timber species in other subtropical and tropical highland environments.

8. RESEARCH NEEDS

The research needs for this system are numerous and urgent, given that this farming system and similar ones are the most important ones that are used to establish new plantings of PNG's major export crop. There is no published formation tc the author's knowledge on the potential of different food species and patterns of admixture of their species or cultivars to provide shade for coffee as well as to produce food; particularly so for bananas which are a critical component of this system. The timing of the various operations appears to be important, but this has not been formally evaluated. The first priority is to study the system and its variations as presently practised by village growers. Some studies have commenced (3, 6) and these need to be expanded.

Once farmer practices have been documented, innovations and potentially superior techniques need to be evaluated in controlled experiments. The growth pattern, nitrogen fixing ability and ecological requirements of *Casuarina oligodon* also require immediate study.

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CAPTIONS

Captions for prints to accompany paper "Food, coffee and casuarina: an agroforestry system from the Papua New Guinea Highlands".

1. Young coffee and casuarina seedlings in a mixed planting with food crops (highland "pitpit", *Colocasia* taro etc.) and some mature casuarina trees (Ambum Valley, 2000 metres).

2. Young bearing coffee (ca 3-4 years) shaded by triploid bananas and some casuarina. Other food crops have all matured by this stage (Nembi Plateau, 1700 metres).

INTERCROPPING UNDER COCONUTS IN SRI LANKA*

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ABSTRACT

Coconut is a major commercial crop of Sri Lanka. Growing a number of other crops in association with coconuts is a widespread practice in all coconut-growing areas of the country. The rationale for the practice is that other crops can profitably be grown between or under the coconuts during the different growth stages of the palms and thus the overall productivity of the land under this long-duration crop can substantially be increased.

The paper gives a concise account of the practice in Sri Lanka indicating the crops most commonly grown as intercrops, arrangement of different crops and early research results on the productivity of the intercrops and their effect on coconuts. Adequate supplies of water and labour are the two major inputs needed for the success of the system. Drought, lack of funds, price instability, lack of technical know-how on intercrop management and problems of timely availability of inputs are the major constraints experienced by farmers in expanding intercropping. Research on both biological and socio-economic aspects is needed to overcome these constraints and extend this potentially attractive system.

Key words: Agroforestry, Coconut, Intercropping, Sri Lanka

1. INTRODUCTION

Coconut (*Cocos nucifera* L.) is cultivated in about 400,000 ha or 25 percent of the total cultivated area of Sri Lanka. It is the most widely cultivated plantation crop of the island nation, the other major two being tea (244,916 ha) and rubber (222,311 ha), and is thus second only to rice (874,221 ha) in terms of the area under the crop. Although coconut is grown in all the districts of Sri Lanka, about 70 percent of the area under the crop is concentrated in the "COCONUT TRIANGE" formed by the districts of Kurunegala, Puttalam, Gampaha and Colombo in the central west coast (Fig. 1). Other important coconut areas include the districts of Kalutara, Galle, Matara and Hambantota accounting for about 15 percent of the total area. The rest of the area is found mostly in the small home gardens in other districts.

FIGURE 1

It is a wide-spread practice in all coconut growing areas of Sri Lanka to grow a large number of other crops in association with coconuts. The practice has been encouraged by the Government of Sri Lanka since 1973 by introducing several subsidy schemes. This paper examines the situation with respect of coconut intercropping in Sri Lanka and summarizes the results obtained so far. Cattle grazing on pasture grown under coconuts is also a common practice in some parts of the country (4), but this paper does not cover that system in detail.

2. GENERAL DESCRIPTION OF THE AREA

2.1. Biophysical Environment

Sri Lanka is a tropical island located between 5° $55'$ and 9° $51'$ N latitudes and 79° $42'$ and 81° $53'$ E longitudes. The total area is 65,610 km^2, extending to a maximum of 410 km in N-S direction and 225 km

in E-W direction. There are different forms of tropical climates within the country depending on rainfall, temperature and altitude (topography). There are four major rainfall zones (13):

- the West Zone that has more than 500 mm rain per month during May to September (southwest monsoon), with a mean annual rainfall of 2500 mm or over;
- the Intermediate Zone, which is a part of the Wet Zone, with a mean annual rainfall of 1875-2500 mm;
- the Dry Zone with less than 500 mm of rain per month during the southwest monsoon season of May to September and a total annual rainfall of 1250-1875 mm;
- the Arid Zone, which is a part of the Dry Zone with a mean annual rainfall of less than 1250 mm.

In Sri Lanka, coconut is grown most prominently in the low country Wet and Intermediate rainfall Zones as indicated in Fig. 1. It is also grown to some extent in the Dry Zone wherever facilities for irrigation exist. In view of the changing distribution pattern of rainfall followed by unprecedented drought periods, a considerable attention has now been focussed on the subject of supplementary irrigation of coconut plantations during droughts, especially in the Intermediate and Dry Zones. On the basis of hydrogeology of the area and long term rainfall records, it has been estimated that available ground water potential ranges from around 2400 cu. m ha^{-1} per annum in the Wet Zone to 800 cu. m ha in the Dry Zone, without affecting the water table (8).

Temperatures are generally around 27° C with only a slight difference

in the diurnal and seasonal fluctuations. The relative humidity in coconut growing areas is also high with a mean of 85%. There is no marked difference in day lengths between seasons, which favours the cultivation of a wide variety of other crops in major coconut growing areas.

The major soil types found in the coconut belt are generally related to the nature of parent material, topography and agroclimate of the area. In the Wet Zone, for example, the dominant soil type in which coconut is grown is a shallow to moderately deep gravelly clay loam, passing to laterite at depth. In the Intermediate Zone, coconut groves are distributed mainly in the sandy clay loam type of soil passing to soft lateritic subsoil. In the Dry Zone, coconut plantations are either flat or undulating excepting a few low to moderately sloping lands. As such, the majority of coconut plantations in Sri Lanka occupy fertile lands of different agroclimate and soil environment suitable for intercropping with a wide range of crops.

2.2. Land Use Systems

With the exception of the area covered with montane rain forest and wet *patanas* (grass lands), rice cultivation is possible and popular in Sri Lanka in all places lying below 1200 m altitude and having irrigation facilities. Some parts of cultivated land in Sri Lanka, especially in the dry northern and eastern plains and to a lesser extent in the southwest, are under shifting cultivation *(chena)*.

Besides these two cultivated land systems, three big plantation systems are important for the island's economy: rubber, tea and coconut. Rubber plantations are in the wet low country up to an elevation of 700 m and tea up to an elevation of nearly 2300 m, tea

plantations being the only form of land use in areas above 1200 m. Coconut is very important in the internal economy and food system of the country. It used to be a major export crop in the past, but according to 1982 figures (7) about 70 percent of the total nut production was used for domestic consumption, leaving about 30% as the exportable surplus. Coconut therefore has a dual role to play, meeting the increasing local demand as well as continuing to serve the most vital export market. Cacao, cinnamon, cardamon, citronella and pepper as minor export/cash crops also contribute to the economy of Sri Lanka. Forests account for 24.9 percent of the area of the country (9).

Sri Lanka practices a number of agroforestry systems. The most prominent ones are 'chena', which is a form of shifting cultivation, some forms of taungya, intercropping under coconut, Kandy- or Home- or Forest Gardens, growing tea and coffee under the shade of trees and wind breaks/shelter belts (24).

3. STRUCTURE OF THE COCONUT INTERCROPPING SYSTEM

3.1. Components

The growth habit and morphology of the coconut palm permit a number of other crops to be grown with or under it during its different growth stages (18). A large number of compatible crops - both annuals and perennials - are grown under coconuts in different geographic and ecoclimatic regions (10, 12, 14, 15, 16, 18, 19, 21, 25). The major crops grown in association with coconuts in the different climatic zones of Sri Lanka are listed in Table 1.

TABLE 1

Sample surveys of intercropping under coconuts conducted recently

(1, 2, 3) in the Wet and Intermediate Wet Zones indicated that bananas, black pepper, coffee, ginger in that order formed the intercrops most preferred by the farmers. The second group in the order of preference consisted of turmeric, betel, vegetables and pineapple. Factors such as profitability, marketing facilities and convenience were listed as the major reasons for farmers' preference for the crops mentioned.

3.2. Arrangement of Components

The three planting systems recommended for coconuts (sole stands) in Sri Lanka are the square (7.9 x 7.9 m), rectangular (8.5 x 7.3 m) and triangular at 8.5 m equilateral, each system accommodating a density of about 160 palms per hectare (17). In the coastal belt, palm densities are relatively high, often up to 210 palms per hectare.

Based on the evaluation of the pattern of utilization of the basic resources -- soil and solar energy -- in monocrop coconut stands of varying age groups (18, 19), it is now generally accepted that coconut stands can conveniently be intercropped when they are either young (up to about eight years after planting) or fully grown and bearing (after about 25 years after planting). According to these considerations and in view of the age group of palms, it is estimated that 70-80 percent of coconut plantations in Sri Lanka can be intercropped (2, 22, 23).

The crop mixtures that are commonly associated with mature coconuts are as follows:

Coffee/banana

Banana mixed with either ginger/turmenic or pineapple

Pineapple/papaya

Banana/mixed with coffee/cacao

Coffee/black pepper

Cacao/coffee (dwarf San Roman variety)/black pepper

The arrangement of components depends on the nature of the intercrop. Generally speaking, a circular area of about 2 m radius around the palm is felt free of intercrops and the intercrops are grown in the inter-spaces of coconut rows according to the recommended planting system for the sole crop of the intercrop concerned. Fig. 2 indicates a schematic planting pattern involving black pepper, cacao and coffee with coconuts. Photographs of cassava and cacao + black pepper as intercrops with coconuts are given as Figures 3 and 4 respectively to show the planting arrangements of the components.

FIGURE 2

FIGURE 3

FIGURE 4

3.3. Interaction of Components

Theoretical considerations on plant community interactions in multi-species combinations with coconuts have been discussed by Nair (18) in the light of the limited research data that were available at that time. In practical terms, the main expectation from an intercropping system in a perennial plantation crop system is that the overall return from unit piece of land is increased without adversely affecting either the current or the long-term productivity of the main (perennial) crop. At the same time, the returns from the additional crops should justify the adoption of the intercropping practice and should contribute to the long-term productivity of the system. Thus, intercropping in coconut stands is viewed as a means for increasing the total productivity of lands that are "committed" to the coconut crop for up to, say, 70 years (which is the normal life-span of the 'Tall' type that forms the vast majority of coconuts grown all over the world).

Results of intercropping experiments conducted at the Coconut Research Institute (CRI) of Sri Lanka summarized in Table 2 indicate that intercropping resulted in an increase of nut yields of coconut. Similar reports are also available from intercropping trials in India (20, 21, 25). The explanation given for this beneficial interaction is that the palms are benefitted by the manures and fertilizers given to the intercrops, elimination of weeds, soil working and other management practices, etc.

TABLE 2

Some of the other obvious advantages of intercropping include better and more intensive utilization of land, more income and generation of more employment from land already planted with coconut, and income from cash crops.

It is also likely that there will be negative interaction leading to adverse effect on the main crop (coconut) and/or the intercrop. Such effects are likely to arise and be aggravated if the intercrops are not adequately and properly managed. However, practically no quantitative data are available from Sri Lanka on these aspects.

SYSTEM FUNCTIONING

1. Resource Input and Utilization

In Sri Lanka, coconut is generally grown under rainfed conditions. Experimental evidence shows that there would be no serious competition for soil moisture between coconuts and the intercrops if the annual rainfall is over 1900 mm. However, in the Intermediate (rainfall) Zone and the drought-prone Dry Zone, it will be risky to grow coconuts as well as long-duration intercrops with them if irrigation facilities are not available. The earlier-mentioned survey of intercropping (2)

revealed that irrigation facilities were available to 17 percent of the farmers who practised intercropping in the Intermediate Zone.

Labour is one of the other major resources needed for intercropping. A study conducted by the Agrarian Research and Training Institute, Colombo (6) revealed that intercropping in coconut stands resulted in a 300% increase in on-farm employment. Some basic farm management data collected over five years from the intercropping trials at the CRI are given in Table 3. It shows that depending on the type and number of intercrops involved, the requirement of labour and the share of labour cost in the total cost of production increased. While the timely availability of labour could pose a problem in some places, the generation of additional on-farm employment can be a very encouraging aspect in owner-cultivated smallholdings. However only a very small percentage of coconut holdings is owner-cultivated in Sri Lanka (see section 4.4.).

4.2. Production

Some data on the production from intercropping systems have already been presented (Tables 2 and 3). These are from experiments conducted at CRI. Although coconut intercropping is widely practised in all coconut growing areas of the country, quantitative data on production aspects from cultivators' fields have not been systematically collected.

4.3. Protective and Service Aspects

Monocrop stands of coconuts offer only partial coverage of the ground when the palms are young and also as they advance in age when the stems get elongated. Consequently the soil gets more exposed to erosion and degradation during these periods. Incidentally, these are the periods when intercropping is most feasible and desirable. In monocrop coconut

stands, it is a common management practice to adopt soil and water conservation practices such as terracing, preparation of bunds and contour drains and burying coconut husks in pits and trenches near the palms to conserve moisture (5). By practising intercropping and adopting prudent land management practices for the intercrops, much of these soil conservation practices which would otherwise be necessary, could be avoided. Thus intercropping can be a better way for increasing the sustainability of coconut lands.

4.4. Socio-Economic Aspects

In Sri Lanka, coconut holdings of less than 4 ha in size are considered smallholdings. The census of agriculture, 1982, which covered ten percent of coconut holdings in the districts Kurunegala, Gampaha, Colombo and Puttalam of the "coconut triangle" indicated that 55 percent of the total area of coconut in the coconut triangle are composed of such smallholdings (Table 4). There is a rather complex relationship between land ownership, owner cultivation/supervision and intercropping. The vast majority of coconut holdings in the country are not cultivated or supervised by the owners. The general pattern is that the majority of coconut farmers are also engaged in paddy rice (and other crops) cultivation in so much as that smallholders who cultivate their own land seldom practise intercropping because most of their time is utilized for growing rice and other crops (in non-coconut areas). On the other hand, holdings are leased, share-cropped or otherwise managed or supervised by non-owners are intercropped. Sixty-three percent of intercropped coconut holdings are thus cultivated/supervised by non-owners whereas only 26 percent of the non-owner cultivated/supervised holdings are non-intercropped.

TABLE 4

5. CONSTRAINTS AND POTENTIALS

5.1. Constraints

The sample survey of intercropping in coconut lands (2) has identified seven important problems/constraints that are faced by the farmers in expanding their intercropping activity. These, in the order of their relative importance, are: drought, lack of funds, price instability, lack of technical know-how, problems of timely availability of labour, availability of planting materials, and thefts. On an average, each intercropper faced at least three of these problems, their nature and extent being dependant on the size of the holding and type of intercrop. For example, lack of technical know-how and funds and non-availability of plant materials and fertilizers were more acute problems faced by smallholders, whereas droughts, price instability and thefts were reported as general problems affecting all categories of holding sizes.

In addition to the above, marketing of perishable seasonal crops (e.g., passion fruit, papaya, pineapple) and crops that are produced in bulk (e.g. ginger, turmeric) can also be a serious problem. It can be aggravated if intercropping extends to large areas without simultaneously developing processing facilities at the producing centres and/or transportation infrastructure to consuming/processing centres.

5.2. Potentials

Notwithstanding the above-mentioned constraints (which are not insurmountable), the system has a great scope for expansion in Sri Lanka and extrapolation to other areas. In principle, this is a sustainable system provided that necessary inputs are available in proper times and quantities, and the system is managed appropriately. At present,

intercropping practises are being extended to additional coconut areas at an annual rate of 1000 ha, thanks to the several Government subsidy schemes.

6. RESEARCH NEEDS

The constraints identified in the previous section call for research on both biological and socio-economic aspects, and the development of an efficient extension service in order to make coconut intercropping system more productive, economical, adoptable and successful. The agronomic requirements of individual crops when they are grown as intercrops need to be standardized. At the same time, the interaction of crops when they are grown in close proximity need to be studied elaborately so that research results can be obtained on the pattern of sharing of resources and growth factors by all component species of the system. In order to arrive at prudent management recommendations, it is necessary to take into account both complementary and competitive interactions affecting production of individual species as well as total production of the whole system, not only during a short span of time but over a long period on a sustainable basis. A reassessment of the hitherto accepted planting patterns and densities of sole crop coconuts is also worth undertaking with the objective of growing intercrops without adversely affecting the palm's productivity. While most other agroforestry systems consist of perennials that often help impr. soil fertility through continuous addition of leaf litter and other organic materials, coconuts do not add much organic materials to the soil, and, therefore, ways of maintaining soil fertility in coconut intercropping systems through external application of nutrients have to be designed appropriately. Along with studies on these aspects of coconut intercropping system, research on various aspects on the

related system of pasture and grazing under coconuts also needs to be intensified.

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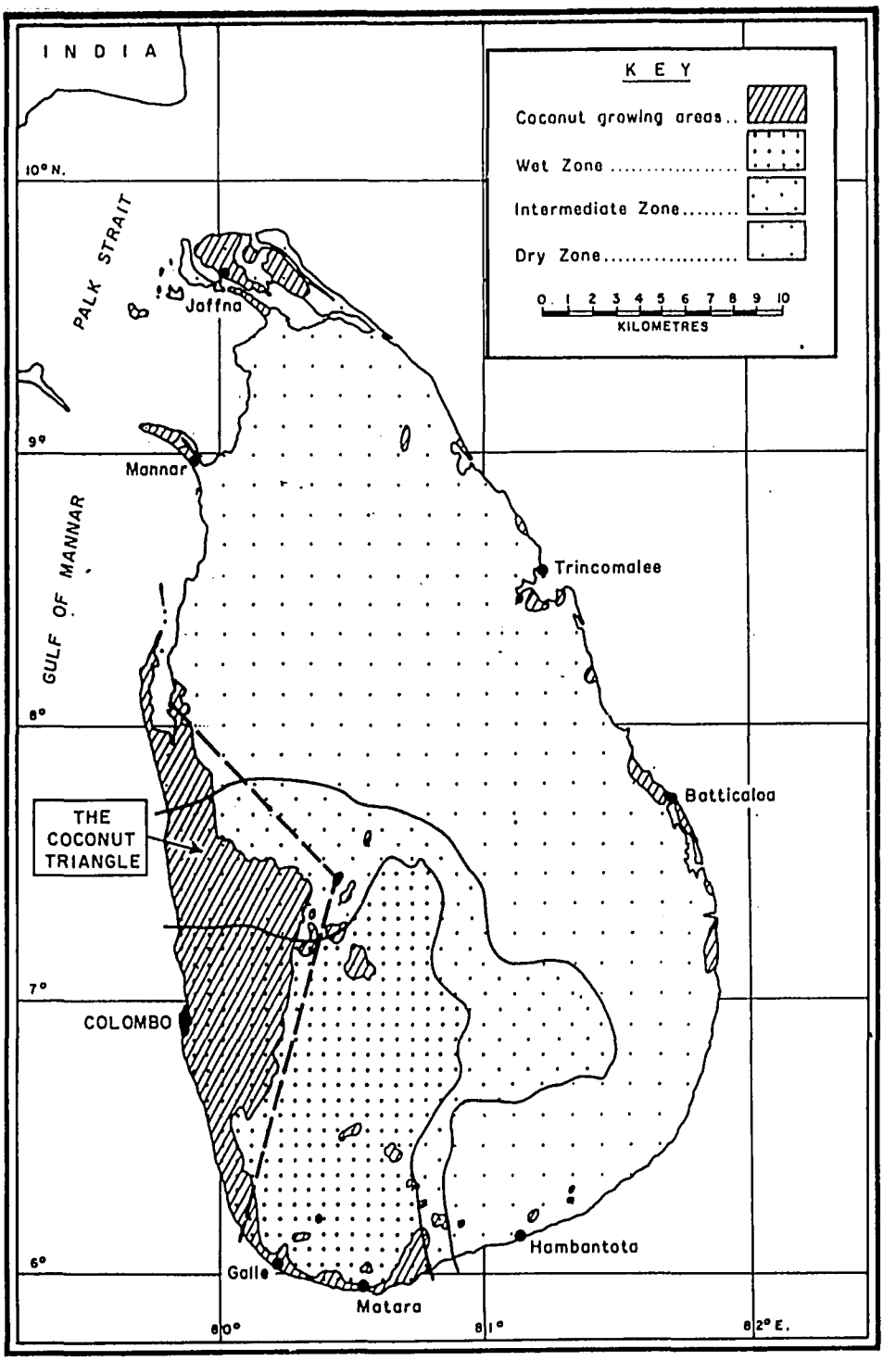

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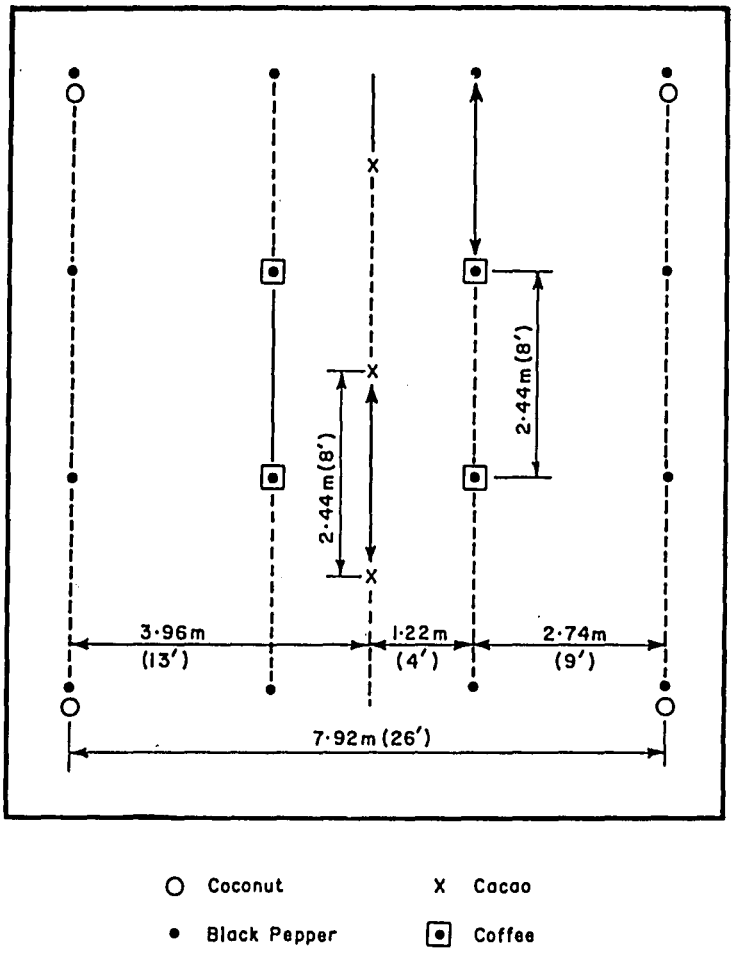

Fig. 2: Schematic patterns for planting black pepper, cacao and coffee as intercrops with coconuts, giving a plant density of 795 black pepper, 550 cacao and 640 coffee per hectare in addition to 159 coconut palms.

Table 2. Yield of coconuts when intercropped with different crops

Intercrops	*Yield of coconuts ha^{-1} yr^{-1}
Clove	5549
Black pepper	5466
Cacao	6738
Cinnamon	7080
Coffee	7318
Annuals in rotation	6825
Control (no intercrop)	5172

* Average of four years' (1978-1981) results at the Coconut Research Institute.

Table 3. * Some Basic Farm Management Data per Hectare on Intercrops Grown with 35-year-old Coconuts

Intercrop(s)	Inputs				Output		Net Income from intercrop	
	Labour (days)	Cost**			Yield (kg)	Value**	Annual	Cumulative
		Labour	Materials	Total				
Coffee								
1st year	144	2520	1685	4205	-	-	- 4205	- 4205
2nd year	77	1348	1380	2728	-	-	- 2728	- 6933
3rd year	89	1558	1725	3283	50	2000	- 1283	- 8216
4th year	112	1960	1625	3235	225	9000	5765	- 1036
TOTAL	514	8996	8040	17036	400	16000		- 1036
Cacao								
1st year	144	2511	1910	4421	-	-	- 4421	- 4421
2nd year	75	1308	1405	2713	-	-	- 2713	- 7134
3rd year	63	1099	1725	2824	65	1625	- 1199	- 8333
4th year	48	837	1625	2462	227	5688	3226	- 5107
5th year	60	1046	1625	2671	525	13125	10454	5347
TOTAL	390	6801	8290	15091	817	20438		5347
Cacao, Coffee and Black pepper								
4th year	209	3662	3200	6862			16972	

* Based on five years data at CRI, Sri Lanka.

** Value in Sri Lanka Rupees; 1 US $ = SL Rs 25 (approx., 1984).

Table 4. Size - class distribution of coconut holdings in the coconut triangle of Sri Lanka

Size, class, category	Hectarage	Percentage
< 0.40 ha	22,996	8.49
0.40 - 2.0 ha	87,907	32.47
2 - 4 ha	38,202	14.11
4 - 8 ha	27,304	10.09
> 8 ha	94,343	34.84

Source: Census of Agriculture, Sri Lanka 1982.

Table 1. Intercrops Grown under Coconuts in Sri Lanka

Type of Crops	Crops		Wet Zone	Intermediate Wet Zone	Intermediate Dry Zone
1. Food Crops					
Tubers	Cassava	*Manihot esculenta*	x	x	
	Sweet potato	*Ipomoea batatas*	x	x	
	Taro	*Colocasia* spp.	x	x	
	Yams	*Dioscorea* spp.	x	x	
Cereals	Finger millet	*Eleusine coracana*			x
	Maize	*Zea mays*		x	
	Sorghum	*Sorghum bicolor*		x	
Legumes	Cowpea	*Vigna unguiculata*		x	x
	Green gram	*Vigna radiata*		x	x
	Groundnut	*Arachis hypogaea*		x	x
	Soybean	*Glycine max*		x	
	Winged bean	*Psophocarpus tetragonolobus*	x	x	
Fruit crops	Banana	*Musa* spp.	x	x	x
	Citrus	*Citrus* spp.		x	x
	Papaya	*Carica papaya*		x	
	Passion fruit	*Passiflora edulis*	x	x	
	Pineapple	*Ananas comosus*	x	x	
	Pomegranate	*Punica granatum*			x
2. Spices and Condiments	Arecanut	*Areca catechu*	x	x	
	Betel leaves	*Piper betel*	x	x	
	Chillies	*Capsicum* spp.	x	x	x
	Ginger	*Zingiber officinale*	x	x	
	Turmeric	*Curcuma longa*	x	x	
3. Miner Export (Cash) Crops	Black pepper	*Piper nigrum*	x	x	
	Cacao	*Theobroma cacao*	x	x	
	Cinnamon	*Cinnamon zeylanicum*	x	x	
	Clove	*Syzygium aromaticum*	x	x	
	Coffee	*Coffea* spp.	x	x	
	Nutmeg	*Myristica fragnas*	x	x	
4. Others	*Pasture grass	*Brachiaria miliiformis*	x		
	Sesame (oil seed)	*Sesamum indicum*			x

* Also see Nair (19)

PERENNIAL CROP-BASED AGROFORESTRY SYSTEMS IN NORTHEAST BRAZIL*

By

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ABSTRACT

Land use systems in the Northeast Region of Brazil are dominated by large holdings and extensive cultivation of perennial crops such as cashew, coconut, carnauba wax palm, babaçu palm and so on. The common feature which links these crops is the silvopastoral system of livestock (chiefly cattle, sheep and donkeys) grazing under them. Agrosilvicultural systems involving cultivation of annual subsistence crops, and in some instances other perennials, in the stands of these perennial crops is also common. The paper presents the available information on the management, production, rate of growth, economic importance, etc. of these agroforestry systems involving cashew, coconut and carnauba palm.

These systems are of considerable merit in the environmental, agricultural and socioeconomic conditions of Northeast Brazil. However, practically no research nor even systematic data collection has been done on these so that there is an almost total lack of information on them. In order to improve the systems, they should be studied in detail and research undertaken on various components (crops, trees and livestock) individually as well as the system as a whole.

Selection of suitable species of grass and other herbaceous crops, appropriate management techniques for both overstorey and understorey species in relation to the age of the overstorey species, optimal stocking rates of animals, etc. have to be determined so as to enable plantation owners and operators to realize the full potential of these systems.

Key words: Agroforestry, Carnauba, cashew, coconut, Northeast Brazil, Silvopastoral systems.

1. INTRODUCTION

Perennial cropping systems are found throughout the Northeast Region of Brazil, under a wide range of rainfall conditions. Since the earliest period of Portuguese colonization, the Northeast has also been characterised, especially in the interior, by extensive livestock grazing. In the present century, agriculture has become more intensive as a consequence of the burgeoning human population of the region and increasing opportunities for agricultural exports. This has resulted in a trend toward combining certain perennial crops and livestock grazing into definable silvopastoral and other forms of agroforestry systems. The major perennial crop components of these systems are cashew *(Anacardium occidentale)*, coconut *(Cocos nucifera)*, babaçu palm *(Orbignya oleifera)* cacao *(Theobroma cacao)* carnauba wax palm *(Copernicia cerifera)* and African oil palm *(Elaeis guineensis)*.

To-date, only a modest amount has been published about agroforestry systems involving these plantation crops. Of these, coconut-based systems have received the most attention. Coconut intercropping systems have been studied and reported from India (7, 9, 10), Sri Lanka (6) and cattle and grazing under coconuts from the Far East and the South Pacific (12, 13, 14, 15, 16). Warui gave a brief account of the crop combinations with cashew and other perennial crops on the Kenyan coast in East Africa (18). Torres has mentioned the viability of the practice of cattle grazing under cashew and coconuts (17). But none of these reports contains any information on the systems in Brazil.

The purpose of this paper is to describe some subtypes of the agroforestry (mainly silvopastoral) systems in the Northeast of Brazil. Cacao-based systems in Bahia State and Babacu-based systems in Maranhão

State are being studied in greater detail by researchers in the two respective research institutions and those systems will be described later in separate contributions to this Series. Information on oil palm-based systems is too fragmentary to be reported. Therefore, this paper concentrates on the systems based on cashew, coconut and carnauba wax palm.

2. GENERAL DESCRIPTION OF THE AREA

The Northeast Region of Brazil has a land area of over 1.5 million km^2 and extends over tropical and equatorial latitudes from 18^oS in the State of Bahia to 1^oS in the State of Maranhão. Although representing only about 18 percent of the national territory, it contains approximately 30 percent of Brazil's 125 million people.

Precipitation is the key environmental factor of ecological significance for the region and can be characterised by three major zones trending northeast to southwest. First is a narrow humid coastal strip in the east which receives an average of 1250 mm to over 2000 mm of rainfall per annum. Second is a middle zone of moisture deficiency which accounts for the largest portion of the Northeast. Most of this zone receives less than 1000 mm of annual rainfall, with an extreme low of less than 300 mm in one small area. The third zone is one of high rainfall, over 2000 mm per year, in western Maranhão. Reflecting this wide diversity of moisture conditions are natural vegetation patterns ranging from tropical rainforest to semiarid thorn scrub.

Given such a large land area, only very broad generalizations can be made about soils. FAO Soils Map of the World shows that the region is dominated by highly weathered, leached Luvisols, Ferralsols and Acrisols,

with dry sandy Arenosols and Regosols common along the coast (1). Topography in those locations where cashew, coconut or carnauba occur or are cultivated is nearly flat.

Land use systems in the Northeast are dominated by large holdings, a pattern which has its origins in the early land grants received by Portuguese colonists. In coastal areas, land was most often devoted to sugarcane monoculture, whereas in the interior large livestock ranches were the rule. Traditionally, beef cattle have been driven to the better-watered coast during the long dry season in the interior. Recently-harvested sugarcane fields, as well as areas of cashew, coconut or carnauba had been used for such seasonal grazing. Even with the modernization of perennial crop agriculture in the present century, these systems have been retained because of their benefit to both the land-owner and the cattleman. Increased raising of dairy cattle along the coast is also associated with plantation agriculture. Along with the improvement of perennial crops themselves has come the improvement of cattle breeding stock and the cultivation of better grass species for planting beneath the tree crops. Fig. 1 shows a sketch map of Northeast Brazil showing the areas where the system(s) being described here can be found.

FIG. 1 HERE

STRUCTURE OF THE SYSTEM

The common feature which links cashew, coconut and carnauba is livestock grazing (silvopastoral system). Cultivation of annual subsistence crops and in some instances other perennials in the stands of these perennial crops (agrosilvicultural system) is also common.

Both cashew and carnauba are native to Northeast Brazil and wild stands have a long history of exploitation. The Portuguese introduced the coconut to coastal Brazil during the 16th century where it quickly became naturalized. Thus under conditions of subspontaneous growth it is equivalent to the stands of the two native species. In addition to gathering the economic products of these three trees, the land areas they occupy are also traditionally used for other agricultural purposes. Locally-raised livestock -- chiefly cattle, goats and donkeys -- are grazed on spontaneous grass and shrub growth beneath the trees and, as already mentioned, so are cattle brought in from the interior for seasonal grazing, and these tree stands provide the much-needed shade to the livestock. Livestock are removed from the fields during the harvesting of cashew fruits and carnauba palm leaves. Fig. 2 shows a coconut plantation with spontaneous grasses, typical of the type used for cattle grazing. Fig. 3 is of a natural stand of carnauba palms with grazing of donkeys. Crowns of the palms are sparse because of leaf harvest.

FIG. 2 AND FIG. 3 HERE

It is also a common practice to clear small plots within the stands of trees to plant subsistence crops during the annual rainy season. Typically, maize, beans and cassava are grown. Individual plots are fenced to keep the livestock out; however, once the crops have been harvested they are allowed to browse on the stubble.

Under formal plantation cultivation of cashew, coconut or carnauba, the components are slightly modified. Basically the change involves cultivation of subsistence catch crops between the rows of trees for the first few years of their growth. Once again, maize, beans and

cassava are the rule. On very large holdings which are mechanized, industrial catch crops such as grain sorghum, peanuts, sesame *(Sesamum indicum)* or cotton are planted. This industrial catch cropping is most often found on cashew plantations. The choice of a particular crop depends upon environmental conditions and the presence of local demand for the commodity.

Once catch cropping is phased out as the trees increase in size, spontaneous grasses replace them or pasture grasses are planted as permanent ground cover. Native ginger grass *(Paspalum maritimum)* and African Guinea grass *(Panicum maximum)* have proven to be successful on cashew plantations (5). Thus in contrast to what occurs with native stands, when these perennial crops are formally cultivated, grazing replaces annual cropping after a few years, rather than coexisting with it.

Occasional intercropping of cashew, coconut or carnauba with other perennial crops is also practised in the region. But this represents a variation of the system where the high planting densities of the main crop exclude livestock and annual cropping. For example, in southern Bahia, there is limited use of coconut to provide cacao with shade and protection from wind. In the elevated areas of Pernambuco where coffee is grown, some older plantings are shaded with cashew trees (Fig. 4). Reportedly in Ceará, cashew trees are utilized to provide support for pepper vines. On very small farms one can see coconut and cashew, cashew and citrus, and cashew, banana and coconut interplanted. Carnauba is not found in association with other perennial crops.

FIG. 4 HERE

4. SYSTEM FUNCTIONING

In Brazil too, like in nearly every other country, agricultural statistics are reported separately under headings of annual crops, perennial crops and livestock. Moreover, statistics are also published on the quantities of products gathered from wild plants in Brazil. Cashew is included as both a perennial crop and a gathered product, coconut as a perennial crop only, and carnauba as exclusively a gathered product. Under such circumstances it is impossible to determine the area of the respective crops which is currently associated with livestock grazing, or the degree to which intercropping of annual crops exists. Nevertheless, the statistics available on perennial crops can be examined to gain a rough idea of the situation. The figures cited in the following discussion are from FIBGE (2, 3).

In 1980, an area of 184,151 ha was enumerated for cashew plantations in the Northeast. Also that year, 18,387 t of unshelled nuts were gathered from natural stands. Conservatively, a cashew tree in Brazil yields about 2 kg of nuts per year. Thus 9,193,500 trees can be estimated to have provided the total. Using the common plantation density equivalent of 100 trees per ha, this would represent 91,935 ha. Therefore 276,086 ha of cashew trees can be used as an approximate total. The coastal areas of Ceará and Rio Grande do Norte states account for more than 70 percent of this national total (Fig. 1). In addition to the cashew nuts which furnish high-value kernels and the industrially valuable cashew nut shell liquid, the fleshy peduncle or apple of the fruit supports small local industries which produce juice and several types of preserves for the domestic market. Kernels and shell liquid are exported.

The area under coconut is less complicated to determine, and in 1980

totalled 164,779 ha for all of Brazil. Over 60 percent of Brazil's total production of coconuts is from the coastal strip, about 50 km wide, in the states of Alagoas, Sergipe and Bahia (northern parts) (Fig. 1). About 10 percent occurs outside the Northeast Region. On the average, a coconut palm yields 25-30 nuts per year in Brazil. Green coconuts are harvested for direct consumption of coconut water as a beverage. Mature nuts support an industry which produces coconut milk and grated coconut; copra is not made. Locally the palm leaves are utilized for thatching and fencing. Brazil does not export coconut products.

As far as the carnauba palm is concerned, no statistics on area are available, although the stands of native trees are estimated to number in the hundreds of millions. Major concentrations are to be found in the river valleys and coastal lowlands of Piauí, Ceará and Rio Grande do Norte (Fig. 1), which account for more than 90 percent of the carnauba wax produced in the country. An indeterminable number of palms have been planted, at densities of 800-1200 per ha, but the practice apparently ended in the 1950s. The palm furnishes two economic products: wax from the leaf surface which has many industrial uses, especially in the food industries because it is edible; and leaf fibre which is the raw material for a small, exclusively domestic, cottage industry of making hats, baskets, etc. In 1980, wax production amounted to 18,857 t, all from the Northeast. At a wax yield of 5 g per leaf, and each tree providing 20 leaves per year, a single palm would produce 100 g (4). Thus 1980 production involved 188,570,000 palms. Wax has been a Brazilian export since the middle of the 19th century. Carnauba leaf fibre production in 1980 was reported to be 1398 t. Although no statistics are collected, carnauba wood is widely used in the Northeast for construction purposes.

According to information obtained in the field, livestock raising is most often found in associations with cashew, coconut or carnauba on large landholdings. On cashew plantations, grazing is not practised the year around; cattle tend to be found in coastal areas, goats in the interior. Smallholders typically do not have the capital to invest

in cattle, but may run a few head of goats or donkeys and an occasional hog or two. No information on stocking rates for plantation grazing is available. Plucknett states that the carrying capacity of one hectare of coconut plantations in Sri Lanka is 1.25 to 5 head of small Sinhala cattle (12).

In socioeconomic terms, these three perennial cropping systems are quite labour intensive, but only on a seasonal basis. Harvesting of cashew nuts and apples, coconuts and carnauba leaves is all done by hand, as is a significant portion of the subsequent processing. Fortunately for these agroindustries, Northeast Brazil has a sizeable rural populations which does seasonal harvest labour to supplement their income as subsistence-level farmers.

6. SYSTEM DYNAMICS

Over the past few decades, each of these three tree crops has experienced different rates of change. Area under cashew has increased considerably due to the establishment of large-scale plantations. Before the Brazilian government initiated a major programme to encourage cashew cultivation in the late 1960s, there were probably no more than a few thousand hectares under actual plantation conditions, and prior to that, virtually all of the cashew nuts came from natural stands. The new programme proved to be a powerful stimulus to agri-business and led to the establishment of some 180,000 ha of modern cashew plantations, most of which were at a density of 100 trees per ha. Many of the new plantations are engaged in catch cropping of subsistence and industrial crops, and some have subsequently converted the areas to pasture for grazing.

Below-average rainfall during the period 1979-1983 led to some losses

of cashew trees, particularly on plantations in areas of poorer soil. Not unexpectedly, insects and diseases affecting cashew have also become more serious. These factors have prompted a period of retrenchment with plantations placing greater emphasis on cattle raising. In order to make that more feasible, new plantings are at a density of 51 trees per ha to allow more open area for grass growth. On some plantations, the earlier more dense plantings have been thinned. The state of cashew cultivation today is difficult to generalize because on the one hand, some plantations are without livestock, whereas there are establishments which have livestock as a primary objective and cashew growing as a secondary activity, on the other.

Area under coconuts has also undergone a strong and steady expansion. From 73,583 ha in 1960, it increased to 117,193 ha in 1970 and to 164,779 ha in 1980. Currently the Brazilian government has a major programme under way to encourage the establishment of new large-scale plantations of coconut, which although focussed on the Northeast, also includes the Amazon Region. Part of the programme is to make available improved coconut varieties, including dwarfs, for the new plantings as well as for the needed replacement of older plantings. Since this programme involves large holdings almost exclusively, there exists the potential to expand the practice of plantation grazing.

Quite a different pattern is found with regard to the carnauba palm. Wax production, which stood at 10,982 t in 1960, nearly doubled to 20,378 t in 1970, but declined in 1980 to 18,857 t. The major reason for this decrease is attributable to the substitution of artificial waxes for carnauba in many of its nonfood uses. However, this decline in production does not reflect any decrease in the number of palms. When demand for wax is slack, the trees are simply not harvested.

Some minor losses of palms do occur when land is cleared for other purposes, but since the carnauba's native habitat is on poorly drained sites and flood-plains, there is minimal conflict of land use. Moreover the palms reproduce vigorously.

The performance of the perennial crop-based system appears to be favourable in the case of cashew and coconuts, but marginal for carnauba because of economic factors. Even without much wax harvesting, however, the multiple utility of the carnauba and its compatibility with grazing and annual cropping assures a continuation of the subtype. High demand for meat on domestic and foreign markets has made livestock more and more attractive to agri-business concerns. In fact, properly managed livestock raising on plantations should increase their sustainability and avoid over-reliance on a single commodity.

EVALUATION

The system discussed in this paper has considerable merit in the context of the environmental, agricultural and socio-economic conditions in Northeast Brazil. From an environmental standpoint, establishment of new plantations of cashew or coconut represents an upgrading of the vegetative cover in most areas of occurrence, from what currently exists. There is a strong justification for protection of native stands of carnauba because of their multiple utility. Plantation grazing is an environmentally sound practice, and adheres to the general recommendation that grazing is a preferred system for the dry savanna climates characterizing so much of the Northeast (8).

Agriculturally, the diversity of this perennial crop-based agroforestry system offers the advantage of making more efficient use of labour and equipment over the entire calendar year, thereby avoiding the peaks and

slacks of activity associated with monoculture. Plantation grazing does however have a few disadvantages too. Careful management practices must be followed to prevent animals from physically damaging young trees. Moreover, when natural stands are utilized, such as with the carnauba, grazing may, over time, hinder natural replacement of trees due to browsing on young leaves and trampling of seedlings. Livestock grazed beneath cashew trees can eat unutilized cashew apples, but excessive quantities should not be allowed because of their high tannin content. Domestic animals also feed on the small carnauba fruits which fall to the ground. There is no general agreement among agronomists as to the advisability of grazing on plantations. Ohler (11) recommends against it, though from a rather narrow monocultural viewpoint. Plucknett views grazing on coconut plantations as an acceptable practice, and one which especially benefits smallholders (12). Similar results have also been reported from studies in the Solomon islands (13, 14, 15, 16). With respect to Northeast Brazil, the long tradition of a variety of successful grazing systems cannot, in any case, be ignored.

There are a number of socioeconomic benefits from this system in the Northeast. The international market for cashew kernels is strong and elastic, and good potential exists for increased domestic utilization of the cashew apple. Coconut products enjoy high demand within the country, which is providing an incentive for expansion of the crop. The future of carnauba wax as a raw material is not very promising. Apparently international markets are undergoing an adjustment which will likely stabilize demand at a level below current production. Economically, livestock raising is profitable in the Northeast, and the combining of it with cashew or coconut should strengthen the economic base of the individual plantation.

In social terms, the growth of agro-industry in the region creates new industrial employment. Given the large rural labour pool, there is not a strong incentive to mechanize plantation operations. In the rural areas, local inhabitants also benefit to a degree from having free or very inexpensive sources of thatch, wood, etc. from the plantations. Social reasons may, in fact, be the overriding justification for encouraging the expansion of perennial-crop based systems.

8. RESEARCH NEEDS

It is obvious from the above description that although the system is practised over extensive areas and it has a number of merits, there is an almost total lack of information on its various management details. Practically no research, not even systematic survey and data collection, has been done on the system, so that no quantitative information is available on many, if not any, of the basic aspects. Therefore the first essential step in improving the system will obviously be to collect quantitative information on the functional and dynamic aspects. These should include current levels of production of various components, as well as the rate of change of production of components with time. It is important to note that not only will the production of grass or other understorey species vary depending upon the age (and consequent interaction effects) of the overstorey species, but also the pattern of production of components of the system at a given growth stage or age of the overstorey species would have changed over a span of few years in a region. Once these data are assembled, the logical next step will be to examine the reasons for the observed behaviour and see how the efficiency of production could be improved. This will involve research on a large number of management aspects of the individual components as well as of the system.

The role of livestock in this system needs to be studied in more detail. Research must be conducted to ascertain optimal stocking rate, which, in turn, will involve all the related aspects such as the species of grass, the type and breed of livestock, management of overstorey and grass species and so on.

Plantation owners and operators need to have better general and crop/site-specific management techniques so that the full potential of this system can be realized.

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(Photo: D.V. Johnson)

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(Photo: D.V. Johnson)

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(Photo: D.V. Johnson)

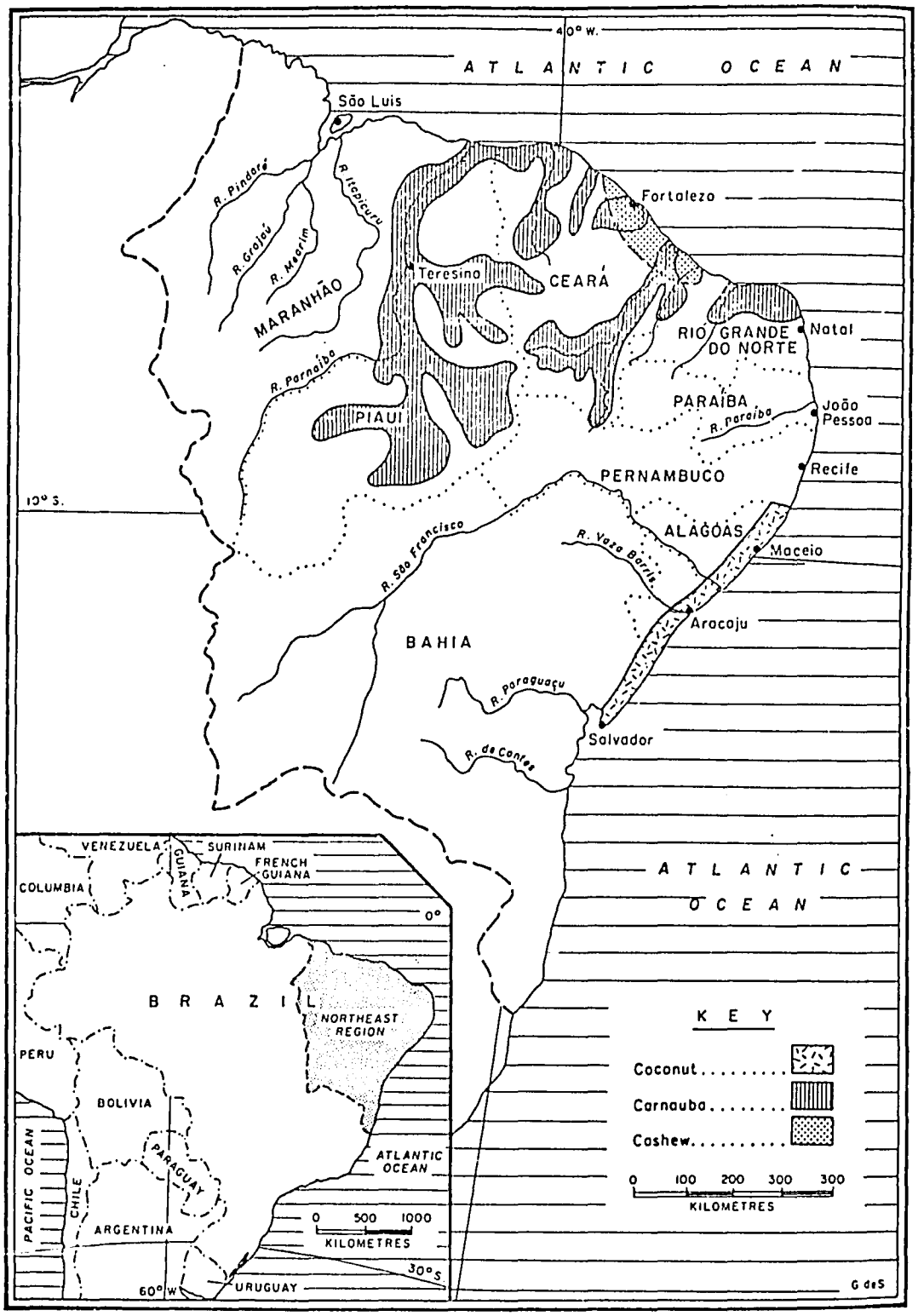

FIG. 1: JOHNSON, D.V. and NAIR, P.K.R: AFS Descripti...

Annex 18

TROPICAL AGROFORESTRY SYSTEMS AND PRACTICES

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Chapter No. 14

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SUMMARY

Agroforestry is a new field of organized scientific pursuit although the practice encompasses some age-old land use activities. It involves elements of agriculture and forestry, wherein woody perennials are deliberately mixed or retained with crop or animal production units.

A global overview of the current agroforestry situation indicates that there are several examples of agroforestry systems and practices in different ecological and geographic regions of the world, especially the tropics. Depending on the dominant components, these systems can broadly be classified into agrosilvicultural, silvopastoral and agro-silvopastoral. Prominent examples of each are given from different parts of the tropics.

The role of woody perennials in agroforestry systems can be both productive (producing food, fodder, fuel, wood, etc.) and protective (soil conservation, windbreaks and shelterbelts, etc.).

Although agroforestry has the most apparent potential in marginal lands, it can equally be effective in high-potential areas too. In both types of areas, it can have a special role in situations where socio-economic or physical constraints force farmers to produce most of their basic needs from their own land. However, there are several scientific, institutional, developmental and extension constraints and impediments facing the development of agroforestry.

While developing management approaches in agroforestry, special emphasis has to be given to the overall performance of the system, and components may be viewed from such a perspective. Some fundamental aspects relating to the two major disciplinary components of land use systems -- plant and soil -- are also examined in the light of these considerations.

TROPICAL AGROFORESTRY SYSTEMS AND PRACTICES

1. INTRODUCTION

In the recent history of the developments in tropical land use, agroforestry as a term as well as a concept is second perhaps only to multiple cropping in terms of the rate and magnitude of the enthusiasm it has generated. It was not until the publication of the report of Bene et al. (1977) that the term was coined in the international scene, and since then, especially in the last quinquennium, there has been a veritable explosion of interest and activities relating to agroforestry. The word has now become so firmly implanted that despite its alleged linguistic inadequacy as pointed out by some critics (Stewart, 1981) and the likelihood of it being erroneously portrayed as a branch of forestry, it would now probably cause more confusion if another term to encompass the same concept were tried to be introduced and popularised. The concepts and principles of agroforestry have recently been elucidated in several publications from the International Council for Research in Agroforestry (ICRAF) as well as other organizations. However, in view of the newness of the topic, some of these fundamental aspects need to be recapitulated here even at the risk of repetition.

2. AGROFORESTRY APPROACH TO LAND USE

It is certainly not (only) the currently prevalent "fad" for new terminologies that has activated and accelerated agroforestry. As pointed out by Lundgren and Raintree (1983), agroforestry is the first concrete concept that builds on a synthesis of much of the practical experience and scientific knowledge acquired over the past

decades in tropical agriculture, forestry, ecology, soil management and rural socioeconomics. Increasing dependence of modern agricultural technology on high-value inputs on the one hand, and the deteriorating economic situation of most of the developing countries on the other, have caused a renewed awareness about the potentials of age-old conservation farming technologies. At the same time, the seriousness of forest destruction and its alarming consequences are also being increasingly realized. The major cause of deforestation is now recognized to be man's search for more and more areas to produce food to meet the ever-increasing demand for this basic need. Thus, in the wake of the mounting pressures of food and fuel shortage, and the serious environmental problems associated with deforestation, it is no longer prudent to ignore the conservation benefits and the potential for sustained yields provided by agroforestry farming systems based on or involving trees and other woody perennials, some forms of which have been in existence for a long time in various parts of the world.

How to find a definition for agroforestry embodying all these concepts and encompassing all the complexities? Certainly there is no concensus of opinions. Many definitions have been proposed (see Agroforestry Systems 1, 7-12, 1982). Some have even gone to the extent of exaggerated and presumptuous claims that agroforestry, by definition, is a superior and more successful approach to land use than others. The definition that is adopted by ICRAF reads as follows:

> *Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management unit as agricultural crops and/or animals, either on the same form of spatial arrangement or temporal*

sequence. In agroforestry systems there are both ecological and economical interactions between the different components.

This definition implies that:

i) agroforestry normally involves two or more species of plants (or plant and animals), at least one of which is a woody perennial;

ii) an agroforestry system always has two or more outputs;

iii) the cycle of an agroforestry system is always more than one year; and

iv) even the most simple agroforestry system is more complex, ecologically (structurally and functionally) and economically, than a monocropping system.

(Readers interested to know more about these concepts and principles may contact the Information/Documentation Services of ICRAF, P.O. Box 30677, Nairobi, Kenya).

3. VARIETY OF AGROFORESTRY SYSTEMS AND PRACTICES

3.1. Classification of Agroforestry Systems

Whatever the definition of agroforestry, it is now generally agreed that it represents an approach to land use involving deliberate retention of trees and other woody perennials in the crop/animal production fields (Lundgren and Raintree, 1983; Nair, 1983 a; b). If we look at the existing land use systems keeping such a broad concept of agroforestry in mind, we find that several of them can be considered to ecnompass the principles of agroforestry.

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Attempts have been made by various authors to classify the different agroforestry systems. Obviously, a classification scheme will depend upon the purpose for which it is to be used. On a global basis, there can be geographical considerations, and within each geographical region there can be ecological factors that determine the type of systems in a locality. Social factors, especially demographic, coupled with economic background of the population can add another dimension to it. However, the baisc structure of a system is decided primarily by the type and arrangements of its components. Therefore, one of the primary criteria in classifying agroforestry systems is the components that constitute the system.

Following the definition mentioned in section 2, the basic groups of components in an agroforestry system can be two or three: woody perennials, herbaceous crops and/or animals. Since the woody perennial forms the common denominator in all agroforestry systems, a component-based classification scheme will logically have to be based on this predominant component. Here again, the criteria, as pointed out by Torres (1983 a), can be several: the *type* of woody perennial, its *role and function* in the system, the nature of *interaction* between the woody and other components, and so on. All component-based classification schemes of agroforestry systems have so far considered the type of woody perennials as the first step in the exercise, and based on that, three broad subdivisions have been proposed by Nair (1983 d): agrosilvicultural, silvopastoral and agrosilvopastoral.

The agrosilvicultural system combines the production of tree crops (forest-, horticultural-, or agricultural plantation-) with herbaceous crops, in space or time, to fulfill productive or protective roles within the land management systems. Examples can be hedgerow

intercropping (alley cropping), improved "fallow" species in shifting cultivation, multistorey multipurpose crop combinations, multipurpose trees and shrubs on farm lands, shade trees for commercial plantation crops, integrated crop combinations with plantation crops, agroforestry fuelwood production systems, shelterbelts and windbreaks and so on. The silvopastoral systems integrate woody perennials with pasture and/ or livestock. Examples include animal production systems in which multipurpose woody perennials provide the fodder (protein bank), or function as living fences around grazing land or are retained as commercial shade/browse/fruit trees in pasture lands. The agrosilvo-pastoral systems, as the name implies, combine trees and herbaceous crops with animals and/or pastures. The use of woody hedgerows for browse, mulch and green manures and for soil conservation, the crop/ tree/livestock mix around homesteads, etc. are good exmples of this system. It is also a common practice in some places to have sequential patterns (integration in time) of agrosilvicultural phase followed by a silvopastoral one so that initially trees and crops are established, and later on, the crops are replaced with pasture, and animals are brought in.

3.2. Field Examples of Agroforestry Systems in the Tropics

ICRAF is currently undertaking a global inventory of agroforestry systems and practices that exist in the tropics and subtropics. The basic document that was prepared for the project included a preliminary overview of the situation as a "Systems Overview Table" indicating the most prominent examples found in different geographical regions. An up-dated version of the Table is presented as Table 1.

TABLE 1 HERE

The ICRAF survey collects information pertaining to the functioning of these systems, as well as analyzes their merits, weaknesses and constraints with a view to identifying research needs and extending the system to other areas. A summary account of some of these extensively practised agroforestry systems and practices is given in Table 2. (For a more detailed account of the woody species involved, see Nair, 1983 d and Nair et al., 1984). Without going into the details, suffice it to say that there are several extensively practised land use systems which though not known by the name agroforestry, do encompass the agroforestry approach to land use.

TABLE 2 HERE

4. PRODUCTIVE AND PROTECTIVE ROLES OF AGROFORESTRY

The field examples of agroforestry systems and practices presented in Table 2 show that they are not only widespread in different ecological regions, but are also important in terms of the role of woody perennials in producing the basic needs and/or protecting and prologing the sustainability of the system. These primary roles (productive/protective) of the woody perennials,the type of their interactions (temporal/spatial) with the other major components and the spatial arrangement of the components (mixed/zonal) in the major agroforestry systems are summarized in Table 3.

TABLE 3 HERE

4.1. Productive Role

The productive role of the woody perennials in agroforestry systems includes production of food, fodder, firewood and various other products. One of the most promising technologies of this kind that is

applicable in a wide range of situations is the hedgerow intercropping (alley cropping) in crop production fields. Promising results have been obtained from this type of studies conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (Wilson and Kang, 1981), where the practice is called alley cropping. The most promising system based on those trials is *Leucaena leucocephala*/maize alley cropping. IITA studies showed that leucaena tops maintained maize grain yield at a reasonable level even with nitrogen input on a low-fertility sandy Inceptisol, the nitrogen contribution by leucaena mulch on maize grain yield being equivalent to about 100 kg ha^{-1} for every 10 t ha^{-1} of fresh prunings (Kang *et al.*, 1981). The hedgerow intercropping system offers the advantage of incorporating a woody species with arable farming system without impairing soil productivity and crop yields. The potential of nutrient (N) contribution by several candidate species of woody legumes suggests that a wide range of such species could be integrated into crop production systems (Nair, 1984; Nair *et al.*, 1984).

Integration of trees in crop production fields is an essential part of traditional farming systems in the dry regions also. Two typical examples are the extensive use of *Acacia albida* in the groundnut and millet production areas of sub-Saharan Africa (Felker, 1978) and the dominant role of *Prosopis cineraria* in the arid North-Western parts of India (Mann and Saxena, 1980).

The role of woody perennials on farmlands for producing fuelwood is another example of the productive role of species in agroforestry. The seriousness of the fuelwood situation has been well recognized all over the world, so that several initiatives and studies on this aspect are currently being undertaken. Several fast-growing firewood crops,

most of them legumes, suitable for different environmental conditions, have been identified (NAS, 1980); most of them combine well with conventional agricultura crops (Nair, 1980).

In the "animal agroforestry" systems, the woody components could be used either as a source of fodder to improve livestock productivity or to obtain another commodity such as fuel, fruit, or timber. Based on this "productivity objective", silvopastoral systems can be either browse grazing or forest/plantation grazing systems. The role of woody perennials in these systems has been reviewed excellently by Torres (1983 b).

4.2. Protective Role

The protective role of woody perennials in agroforestry stems from their soil improving and soil conserving functions. There are various avenues through which the leguminous woody perennials could improve and enrich soil conditions; these include fixation of atmospheric nitrogen, addition of organic matter through litterfall and dead and decaying roots, modification of soil porosity and infiltration rates leading to reduced erodibility of soil and improving the efficiency of nutrient cycling within the soil-plant system (Nair, 1984). However, the main protective function of woody perennials is in physical conservation of the soil.

The long tradition of planting *Leucaena leucocephala* in contour hedges for erosion control and soil improvement in Southeast Asia, especially Indonesia, is a typical example. Indirect terraces are also formed when the washed-off soil is collected behind the hedges. Loppings and prunings from such hedgerow species could also provide mulch to aid in preventing sheet erosion between trees (Zeuner, 1981; Neumann, 1983). The presence of more plant cover on the soil, either alive or

as mulch, also reduces the impact of raindrops on the soil and thus minimizes splash and sheet erosion. Therefore, as pointed out by Lundgren and Nair (1983), the potential role of agroforestry in soil conservation lies not only in woody perennials acting as a physical barrier against erosive forces, but also in providing mulch and/or fodder and fuelwood at the same time.

Other protective functions of woody perennials in agroforestry include their role as live fences, shelterbelts and windbreaks. Use of trees and other woody perennials to protec agricultural fields from trespassing or against the adverse effects of wind is a wide-spread practice in many agricultural systems. For example, a large number of multipurpose woody perennials are being used as effective live fences at CATIE (Centro Agronomico Tropico de Investigacion y Ensenanza), Turrialba, Costa Rica (Budowski, 1983). Similarly, very encouraging results on shelterbelts and windbreaks have been obtained at the Pakistan Forestry Research Institute, Peshawar (Sheikh and Chima, 1976; Sheikh and Khalique, 1982), as indicated in Table 2.

5. CONSTRAINTS AND POTENTIALS

5.1. Constraints

There are several scientific, institutional, developmental and management constraints and impediments to be overcome before scientifically sound agroforestry technologies can be developed and adopted in areas where other and use systems are breaking down.

Scientifically, agroforestry has no distinct identity or separate existence of its own as yet. By its very nature, it is an integrated and multidisciplinary approach encompassing complex systems. Existing

land use research institutions, both national and international, are mostly oriented to specific commodities, disciplines or ecological regions so that they are poorly equipped to handle complex topics such as agroforestry. The scientists themselves are mostly too discipline-oriented (such as specialists in one or the other branch of agriculture, forestry, animal husbandry, etc.) so that it is not an easy task to persuade them to relegate and reorient their disciplinary pursuits to the interdisciplinary needs of a multidisciplinary team. Moreover, the experimental methods and procedures that have been developed over the decades for specific disciplines and components will have to be modified to make them applicable and relevant to integrated and complex systems, which by no means, is an easy task.

Institutional constraints to agroforestry development are also equally complex. As mentioned in the introductory section of this paper, rigid boundaries often separate departments dealing with different aspects of land use, leading to increasing competition for scarce developmental resources at governmental and administrative levels. As pointed out by Lundgren and Raintree (1983), even in places where formal agroforestry programmes exist, they fall under the forestry departments with very little knowledge of, let alone interaction with, the agriculture departments (which, usually, are more 'prestigious' and 'powerful' than the respective forestry departments). The situation is much the same in the international sphere too. Thus there exists a sort of vicious circle: on the one hand agroforestry has not developed to earn a separate identity in terms of resources allocation, and, such a respectability and identity can, on the other hand, be achieved only by research investments for development.

The transfer of technology to the masses is another big step involved

in the adoption of such land use practices. The majority of the farmers in the tropics are preoccupied by their efforts to find the current basic needs of food, fuel, shelter, etc. so that they cannot easily be bothered about the merits of long-term approaches and investments. Thus, it may be relatively easy to introduce short-term technologies such as new species or better varieties of agricultural crops, or to make marginal improvements in the management of existing tree components. But, it will be considerably more difficult and challenging to convince farmers about incorporation of tree components over existing crop or animal enterprises, especially if land tenure is uncertain and success of the system is not guaranteed. The problem is compounded by poor and inadequate extension services that can seldom handle complex problems such as those of agroforestry.

Management constraints of agroforestry are also several and of varied nature. Special skills and sustained efforts are needed for undertaking the various management aspects of trees, about which many crop or livestock farmers may not be aware of. Interaction between components, especially the hypothetical adverse effects of trees on crops, is an area about which farmers who are not experienced with such systems are very apprehensive, and researchers are not equipped enough to allay such apprehension. It is interesting to note in this context that a survey on the extent of intercropping in coconut lands in Sri Lanka identified seven important problems/constraints that are faced by the farmers in expanding their intercropping activity (Liyanage *et al.*, 1984). These, in order of their relative importance, were: drought, lack of funds, price instability, lack of technical know-how, problems of timely availability of labour, availability of planting materials, and thefts. On an average, each intercropper faced at least three of these problems,

their nature and extent being dependant on the size of holding and type of intercrop.

5.2. Potentials

Notwithstanding the above-mentioned constraints, agroforestry has great potential over vast areas of land. As indicated earlier, the most apparent potential for agroforestry exists in areas where soil fertility is low and is dependent mainly on soil organic matter fraction, and where erosion hazards are high. And such "marginal lands" cover a majority of land areas in the tropics. Proper integration of appropriate woody species in the land use systems in these areas can enhance both land productivity and sustainability.

However, the potential of agroforestry is, by no means, confined to such "marginal" lands; it is equally applicable to high-potential lands. Indeed, we can find indigenous agroforestry systems wherever there has been a history of population pressure and a long-standing need for efficient management of scarce resources (Lundgren, 1982). Some of the most successful smallholder systems mentioned in Table 2 are, in fact, found on high-potential, fertile soils where such integrated systems are often superior and preferred to other forms of land use. In both low-potential and high-potential areas, agroforestry can have a special role in situations where land tenure system or infrastructural limitations (road, transport, markets, etc.) make it imperative for the farmers to produce most of their basic needs (food, fuel, building poles, etc.) from their own land resources.

The potentia role of agroforestry in production systems producing food, fodder, fuelwood, poles, etc. and in protecting the environment through soil conservation, wndbreak, etc. has already been indicated

in section 4.2. Agroforestry approaches have also been suggested as alternatives to resource-depleting shifting cultivation (Nair, 1983 d) as well as in other specific environments (Nair, 1983 c). It has also a special role in combating desertification and deforestation because the primary reason for forest destruction is man's ever-increasing demand for more land for producing food and agroforestry offers possibilities for producing food and wood at the same time from the same piece of land (King, 1979; Nair, 1982).

6. MANAGEMENT APPROACHES FOR DEVELOPMENT OF AGROFORESTRY SYSTEMS

Basically, there are two approaches in the study of an entity. First, to consider the different components and study them individually, paying particular attention to their cause-effect relationships. Most of the agricultural research conducted in the past has been of this nature, and these studies have helped us to improve our knowledge considerably. However, problems often arise when we try to put the pieces together and predict the behaviour of the system, which often consists of something more than the individual components. The second approach is to study the system in its totality -- a system will, of course, be considered to consist of different sub-systems.

In agroforestry, the individual components to be studied and their interactions are many. Moreover, the studies are normally of a very long-term nature. Inadequate planning and uncoordinated data-gathering without a central theme, as is likely to occur in individual disciplinary experiments, might lead to the drawing of incorrect conclusions with respect to the system as a whole. In addition, the extrapolation of results obtained from such piece-meal research might be extremely dangerous. Therefore, the technological assessment in agroforestry

research should concentrate less on types of component analyses, in which the factors and organisms are treated as if they were independent entities, but focus more on approaches in which the interactive, integrative, and emergent properties are also included.

This is, however, not to suggest that approaches aiming at gathering basic information on the components of the system are not required. In fact, when the land use system is examined in its totality certain aspects of the components that need to be studied in detail to produce the expected technologies will come to the fore. In most cases, such technologies and management approaches that will require immediate attention will be related to plant and soil components.

6.1. Plant Aspects of Agroforestry

Because of the newness of agroforestry, there are no conventional plant species that can be categorized as "agroforestry species". All species that can grow well in combined production systems fall under the domains of "agricultural, "forestry", "horticultural", or other established classes. Therefore, what is important is to examine the "suitability" of economic plant species to agroforestry, no matter whether it is known to belong to any of the conventional disciplinary groups. Nair (1980) examined the "agroforestry potential" of several of the better-known as well as lesser-known "agricultural" and "horticultural" species and found that most of them can grow and produce reasonable yields under combined production systems.

When considering integration of trees on farmlands where some agricultural species are already being grown, it is assumed that there will be little or no change in the type of such herbaceous species: they will continue to be limited to what the local population or established

markets require. On the other hand, the compatability and complementarity of the woody perennial with such herbaceous species will be the important consideration. In addition to the genotype of the woody species as such, its resource-sharing capabilities, potential micro-site enrichment capability, and environmental amelioration are also or prime importance. Thus, appropriate management measures (pruning, lopping, pollarding, browsing, time of sowing in the case of herbaceous species) have to be practised in order to optimize the benefits in combined production systems. Peculiar phenological characteristics of economically useful species may become very convenient in some contexts. A typical example is the tree *Acacia albida,* which produces leaves prior to the onset of rains and shed the leaves during rainy season, so that millet and groundnut can be grown close to the tree in the rainy season without being shaded, and at the same time they can benefit by the micro-site enrichment by the tree (Felker, 1978).

Plants, especially woody species, that have hitherto been very little studied and understood may prove themselves to be very valuable for agroforestry. Prime candidates will be species that can grow well with other species, that thrive in environments that are too harsh for most other species, that simultaneously yield several products (food, fuel, fodder), that provide environmental amelioration (e.g. soil conservation) and that enrich the micro-site, such as by nitrogen fixation or nutrient cycling. Luckily, a few species have been identified that possess some, if not all, of these attributes (NAS, 1975; Ritchie, 1979), and they are now receiving scientific attention.

Arrangement of component plant species in space and time is also an important but difficult factor in agroforestry because of the many variations in the types of agroforestry practices and the conditions

under which they are practised. The motivation for most of the various kinds of smallholder agroforestry systems that are prevalent throughout the world (Tables 1 and 2) has been to find plants that provide multiple products and that can be grown on the available land. When attempting to improve such systems or to devise new ones, it therefore is necessary, to know about both the short-term productivity of the plants and the long-term sustainability of the system. Thus depending on whether the tree-crop interaction is favourable or not,plant arrangements have to be devised to maximize the beneficial interactions and minimize the undesirable ones. There are also several other factors to be taken into account. Examples include: growth habits and growth requirements of the component species when grown near other species, simplicity of management procedures for the whole system, and realization of additional benefits like soil conservation. These plant aspects of agroforestry were brought out in considerable detail in an expert consultation organized by ICRAF (Huxley, 1983).

6.2. Soil Aspects of Agroforestry

State-of-the-art of soils aspects of agroforestry was brought out in an ICRAF Consultation in 1979 (Mongi and Huxley, 1979). Since agroforestry is particularly suitable for farmers with limited resources in marginal areas, where sedentary agriculture or forestry systems may not be the most feasible and desirable, the system must be self-maintaining. This means that the system should attain maximum efficiency in inputs and maintain productivity of soil with a strong emphasis on resource conservation. In view of the importance of the self-sustaining and resource-conserving attributes of agroforestry, the likely effects of agroforestry on long-term productivity of soil have been examined using existing knowledge derived from similar land

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use systems (Nair, 1984). This involved an evaluation of soil productivity changes under shifting cultivation, taungya, plantation forestry, integrated systems involving plantation crops and multiple cropping. It also entailed an assessment of the role of trees in soil productivity and protection.

The analysis revealed that several advantages in terms of soil productivity and protection could be anticipated by proper incorporation of appropriate woody species in land use systems. Some expedient soil management technologies of a general nature were also suggested based on these considerations.

In conclusion, agroforestry has generated a lot of enthusiasm among various groups of people. There are several types of agroforestry systems and all of them are very complex in nature. The scientific approach to the study of these complex systems is difficult, time-consuming and needs multidisciplinary input. Most of the hypothesis concerning the potential as well as management approaches of agroforestry are still in the hypothetical and speculative stage. In order to validate the hypotheses and devise sound management technologies, research has to be undertaken on these various aspects in a systematic manner in different agro-ecological situations. While interpreting results from such research and trying to extrapolate them to other situations, the overall systems perspective of agroforestry has to be given adequate attention.

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TABLE 1. SOME EXAMPLES OF PROMINENT AGROFORESTRY SYSTEMS AND PRACTICES IN THE DEVELOPING COUNTRIES

S Y S T E M S		E X A M P L E S F R O M D I F F E R E N T G E O G R A P H I C R E G I O N S *						
Major Systems	Sub-Systems/Practices	Pacific	Southeast Asia	South Asia	Middle East and Mediterranean	East and Central Africa	West Africa	American Tropics
AGROSILVICULTURAL SYSTEMS	Improved "Fallow" (in shifting cultivation areas)		Forest villages of Thailand Various fruit trees & plantation crops used as "fallow" species in Indonesia	Improvements to Shifting Cultivation; several approaches e.g. in the north-eastern parts of India		Improvements to Shifting Cultivation e.g. gum gardens of the Sudan	*Acacia barteri*, *Anthonotha macrophylla*, *Gliricidia sepium*, etc. tried as "fallow" species	Several forms
	The Taungya System	(e.g. Taro with *Cedrella* and *Anthocephalus* trees)	Widely practised; Forest villages of Thailand is an improved form	Several forms, several names		The 'Shamba' System	Several Forms	Several forms
	Tree Gardens	Involving fruit trees	Dominated by fruit trees	In all ecological regions	The Dehesa system; "Parc arboré"			e.g. 'Paraiso Woodlot' of Paraguay
	Hedgerow Intercropping (Alley Cropping)		Extensive use of *Sesbania grandiflora*, *Leucaena leucocephala* and *Calliandra calothyrsus*	Several experimental approaches e.g. Conservation Farming in Sri Lanka		The Corridor System of Zaire	Experimental systems on alley cropping with *Leucaena* and others	
	Multipurpose Trees and Shrubs on Farmlands	Mainly fruit or nut trees (e.g. *Canarium*, *Pometia*, *Barringtonia*, *Pandanus*, *Artocarpus altilis*)	Dominated by fruit trees; also *Acacia mearnsii* - cropping system, Indonesia	Several forms both in lowlands and highlands e.g. Hill Farming in Nepal; 'Khejri' - based system in the dry parts of India	The Oasis system; Crop combinations with the Carob tree; The Dehesa system; Irrigated systems; Olive trees + cereals	Various forms; The Chagga system of Tanzanian highlands; The Nyabisindu system of Rwanda	*Acacia albida*-based food production systems in dry areas; *Butyrospermum* + *Parkia* systems; "Parc arboré"	Various forms in all ecological regions
	Crop Combination with Plantation Crops	Plant. crops and other multipurpose trees: e.g. *Casuarina* and coffee in the highlands of PNG; also *Gliricidia* and *Leucaena* with cacao	Plant. crops + fruit trees; smallholder systems of crop combinations with plantation crop; plantation crops with spice trees	Integrated production systems in smallholdings; shade trees in plantations; other crop mixtures including various spices	Irrigated systems; Olive trees + cereals	Integrated production; shade trees in commercial plantations; mixed systems in the highlands	Plantation crop mixtures; smallholder production systems	Plantation crop mixtures; shade trees in commercial plantations; mixed systems in smallholdings; spice trees
	AF Fuelwood Production	Multipurpose fuelwood trees around settlements	Several examples in different ecological regions	Various forms		Various forms	Common in the dry regions	Several forms in the dry regions
	Shelterbelts, Windbreaks, Soil Conservation Hedges	*Casuarina oligodon* in the highlands as shelterbelts and soil improver	Terrace stabilization in steep slopes	Use of *Casuarina* spp. as shelterbelts; several windbreaks	Tree spices for erosion control	The Nyabisindu system of Rwanda	Various forms	Live fences, windbreaks especially in highlands
SYLVOPASTORAL SYSTEMS	Protein Bank (Cut-and-carry Fodder Production)		Very common, especially in highlands	Multipurpose fodder trees on or around farmlands especially in highlands		Very common	Very common	Very common
	Living Fence of Fodder Trees and Hedges		*Leucaena*, *Calliandra*, etc. used extensively	*Sesbania*, *Euphorbia*, *Syzigium* etc. common		Very common in all ecological regions		Very common in the highlands
	Trees and Shrubs on Pastures	Cattle under coconuts, pines and *Eucalyptus deglupta*	Grazing under coconuts and other plantations	Several tree species being used very widely	Very common in the dry regions; the Dehesa system	The *Acacia* dominated system in the arid parts of Kenya, Somalia and Ethiopia	Cattle under oil palm; Cattle and sheep under coconut	Common in humid as well as dry regions e.g. Grazing under plantation crops in Brazil
AGROSILVOPASTORAL SYSTEMS	Woody Hedges for Browse, Mulch, Green Manure, Soil Conservation, etc.	Various forms: *Casuarina oligodon* widely used to provide mulch and compost	Various forms	Various forms especially in lowlands			Very common	
	Home Gardens (involving a large number of herbaceous and woody plants with or without animals)		Very common; Java Home Gardens often quoted as good examples	Common in all ecological regions	The Oasis system	Various forms (The Chagga homegardens; the Nyabisindu system)	Compound farms of humid lowlands	Very common in the thickly populated areas
OTHER SYSTEMS	Agro-Silvo-Fishery ('Aquaforestry')		Silviculture in mangrove areas; trees on the bunds of fish-breeding ponds					
	Various forms of Shifting Cultivation	Common	e.g. Swidden Farming	Very common; various names		Very common	Very common in the lowlands	Very common in all ecological regions
	Apiculture with Trees	Common	Common		Common	Common	Common	

TABLE 2. FIELD EXAMPLES OF SOME COMMON AGROFORESTRY SYSTEMS AND PRACTICES IN THE TROPICS

Sub-system/ Practice	Country/ Region	Some examples of the woody species involved	Remarks/ Major references
I.A. AGROSILVICULTURAL SYSTEMS - Humid/Sub-humid Lowlands			
Improved "Fallow" (in shifting cultivation areas)	Indonesia	*Aleurites molucana* *Erythrina* spp. *Styrax* spp.	Kunstadter et al. (1978)
Woody species planted and left to grow during the "Fallow phase"	Nigeria	*Acioa barteri* *Anthonotha macrophylla*	Getahun et al. (1982)
Tree Gardens	Nigeria	*Daniellia oliveri* *Gliricidia sepium* *Parkia clappertoniana* *Pterocarpus africana*	Getahun et al. (1982)
Multilayer, multi-species plant associations with no organized planting arrangement	Pacific Islands	*Inocarpus edulis* *Morus nigra* *Spondias dulce*	Richardson (1982)
	India, Sri Lanka	*Areca catechu* *Artocarpus* spp. *Cocos nucifera* *Mangifera indica*	Coconut intercropping: Nair (1979; 1983); Liyanage et al. (1984)

TABLE 2 (CONT'D)

	Paraguay	*Melia azedarach*	The Paraiso woodlot (Evans and Rombold, 1984)
	SE Asia	*Albizia falcataria* *Artocarpus* spp. *Bambusa* spp. *Durio zebethinus* *Nephelium lapaceum*	Ambar (1982) Forest Villages of Thailand (Boonkird et al., 1984)
Hedgerow intercropping (Alley cropping)	SE Asia	*Calliandra callothyrsus*	
Woody species in hedges; agri. species in between hedges (alleys)	Nigeria	*Leucaena leucocephala*	Wilson and Kang (1981)
Multipurpose trees and shrubs on farmlands	Brazil	*Cassia excelsa* *L. leucocephala* *Mimosa scabrella*	
Trees scattered haphazardly or according to some systematic patterns	India	*Derris indica* *Emblica officinalis* *Moringa oleifera* *Tamarindus indica*	NAS (1980)
	Kenya	*Anacardium occidentale* *Ceiba petandra* *Mangifera indica* *Manilkara achras*	

TABLE 2 (CONT'D)

	SE Asia	*Acacia mangium* *Artocarpus* spp. *Durio zibethinus* *Gliricidia sepium* *Sesbania grandiflora*	
Crop combinations with plantation crops 1) Integrated production of plantation crops and other crops in intimate plant associations 2) Mixtures of plantation crops e.g. coconut and cacao 3) Shade trees for commercial plantation crops		<u>Plantation crops</u> *Anacardium occidentale* *Camellia sinensis* *Cocos nucifera* *Coffea arabica* *Elaeis guineensis* *Hevea brasiliensis* *Piper nigrum* *Theobroma cacao*	
	Brazil	*Bertholletia excelsa* *Copernicia prunifera* *Cordia alliodora* *Inga* spp. *Orbignya* spp. *Samanea saman*	Hecht (1982) Alvim and Nair (1984)

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TABLE 2 (CONT'D)

	Costa Rica	*Cordia alliodora* *Erythrina poeppigiana* *Gliricidia sepium* *Inga* spp.	Budowski (1983) Heuveldop and Lagemann (1981)
	India	*Albizia* spp. *Cassia* spp. *Erythrina* spp. *Grevillea robusta*	Coconut intercropping (Nair, 1979; 1983; Liyanage et al., 1984)
	SE Asia	Various fruit trees	
	West Indies	*Inga vera*	
	Western Samoa	*Erythrina variegata* *Gliricidia sepium* *Leucaena leucocephala*	Richardson (1982)
AF for fuelwood Production Interplanting fire-wood species on or around agricultural lands	India	*Albizia* spp. *Cassia siamea* *Derris indica* *Emblica officinalis*	ICAR (1979) NAS (1980)
	Indonesia	*Albizia falcataria* *Calliandra callothyrsus* *Sesbania grandiflora* *Trema orientalis*	NAS (1980)

TABLE 2 (CONT'D)

Shelterbelts, windbreaks, soil conservation hedges	India	*Casuarina equisetifolia* *Syzygium cuminii*	NAS (1980)
Planting around agricultural lands as windbreaks and shelterbelts; planting along contours for terrace stabilization and soil conservation	Indonesia (and other parts of SE Asia)	*Gliricidia sepium* *Leucaena leucocephala* *Sesbania grandiflora*	NAS (1980)
I. B. AGROSILVICULTURAL SYSTEMS - Tropical Highlands			
Multipurpose trees and shrubs on farm-lands	India	*Albizia* spp. *Bauhinia variegata* *Dalbergia sissoo*	NAS (1980)
	Kenya	*Ceiba petandra* *Eriobotrya japonica* *Grevillea robusta*	
	Nepal	*Bauhinia* spp. *Erythrina* spp. *Ficus* spp. *Litsea polyntha*	Hill farming in Nepal (Fonzen and Oberholzer, 1984)

TABLE 2 (CONT'D)

	Paraguay	*Melia azedarach*	The Paraiso woodlot (Evans and Rombold, 1984)
	Tanzania	*Albizia* spp *Cordia africana* *Croton macrostachys* *Trema guineensis*	The Chagga system (Fernandes et al., 1984)
Crop combinations with plantation crops	Brazil	*Alnus acuminata* *Enterolobium contorsiliquum* *Erythrina velutina*	
	Costa Rica	*Alnus acuminata* *Erythrina poeppigiana* *Inga* spp.	Budowski (1983)
	India, Sri Lanka	*Albizia* spp. *Grevillea robusta*	
	Kenya Papua New Guinea Philippines	*Grevillea robusta* *Casuarina olygodon* *Trema orientalis*	Bourke (1984)
	Rwanda Tanzania	*Albizia* spp. *Cordia africana* *Grevillea robusta* *Trema guineensis*	Fernandes et al. (1984) Neumann (1983)

TABLE 2 (CONT'D)

AF Fuelwood Production	India, Nepal	*Albizia stipulata* *Bauhinia* spp. *Grewia* spp.	ICAR (1979) NAS (1980)
Shelterbelts, Windbreaks, Soil Conservation Hedges	(same as in lowlands)		
I.C. AGROSILVICULTURAL SYSTEMS - Arid and Semi Arid Regions			
Multipurpose Trees and Shrubs on Farm-lands	Brazil	*Caesalpinia ferrea* *Prosopis juliflora* *Zizyphus joazeiro*	Johnson (1983)
	Central African Republic	*Adansonia digitata* *Balanites aegyptiaca* *Borassus aethiopium*	Yandji (1982)
	India	*Cajanus cajan* *Derris indica* *Prosopis cineraria* *Tamarindus indica*	NAS (1980)
	Kenya	*Acacia* spp. *Balanites aegyptiaca* *Cajanus cajan*	

TABLE 2 (CONT'D)

	Tanzania	*Acacia* sp. *Combretum* spp.	
AF Fuelwood Production	Chile	*Prosopis tumarugo*	NAS (1980)
	India	*Albizia lebbek* *Cassia siamea* *Prosopis* spp.	Little (1983) ICAR (1979)
	Sahel	*Acacia albida* *A. senegal* *A. tortilis*	von Maydell (1984)
Shelterbelts and Windbreaks	India, Pakistan	*Azadirachta indica* *Cajanus cajan* *Cassia siamea* *Eucalyptus* spp. *Pithecellobium dulce* *Populus* spp.	Sheikh and Chima (1976), Sheikh and Khalique (1982)

TABLE 2 (CONT'D)

II. SILVOPASTORAL SYSTEMS - Humid/Sub-humid Lowlands			
Protein Bank (Multi-purpose Fodder Trees on or around Farmlands)	India, Nepal, Sri Lanka	*Artocarpus* spp *Anogeissus latifolia* *Bombax malabaricum* *Cordia dichotoma* *Dalbergia sissoo* *Eugenia jambolana* *Samanea saman* *Zizyphus jujuba*	ICAR (1979) Pandey (1982) Singh (1982)
Living Fences of Fodder Trees and Hedges	Costa Rica	*Diphysa robinoides* *Gliricida sepium*	
	Ethiopia	*Erythrina abyssinica*	
	SE Asia	*Sesbania grandiflora*	
Trees and Shrubs on Pastures (similar to multipurpose trees on farmlands)	Brazil	*Acacia* spp. *Anacardium occidentale* *Cedrela odorata* *Cordia alliodora*	Hecht (1982) Johnson and Nair (1984)
	Costa Rica	*Enterolobium cyclocarpum* *Erythrina poeppigiana* *Samanea saman*	De las Salas (1979)

TABLE 2 (CONT'D)

	India	*Derris indica* *Emblica officinalis* *Psidium guajava* *Tamarindus indica*	Singh (1982)
II. SILVOPASTORAL SYSTEMS - Tropical Highlands			
Protein Bank	Indian subcontinent	*Albizia stipulata* *Bauhinia* spp. *Ficus* spp. *Grewia oppositifolia* *Morus alba*	
Living Fences	Costa Rica Ethiopia East Africa	*Gliricidia sepium* *Erythrina abyssinica* *Dovyalis caffra* *Euphorbia tirucalli* *Iboza multiflora*	
Trees and Shrubs on Pastures	Brazil	*Desmanthus varigatus* *Desmodium discolor*	
	Costa Rica	*Alnus acuminata*	
	Indian subcontinent	*Albizia stipulata* *Alnus napalensis* *Grewia* spp. *Robinia pseudoacacia*	

TABLE 2 (CONT'D)

II. C. SILVOPASTORAL SYSTEMS - Arid and Semi-arid Regions			
Protein Bank	India	*Acacia nilotica* *Ailanthus excelsa* *Opuntia ficus indica* *Prosopis* spp. *Rhus sinuata*	Singh (1982)
Living Fences	East Africa	*Acacia* spp. *Commiphora africana* *Euphorbia tirucalli* *Zizyphus mucronata*	
Trees and Shrubs on Pastures	India	*Acacia* spp. *Prosopis* spp. *Tamarindus indica*	
	Middle East and Mediterranean	*Acacia* spp. *Ceratonia siliqua* *Haloxylon* spp. *Prosopis cineraria* *Tamarix aphylla*	

TABLE 2 (CONT'D)

III. AGROSILVOPASTORAL SYSTEMS			
Woody Hedgerows for Browse, Mulch, Green Manure and Soil Conservation	Indian subcontinent (Humid lowlands), SE Asia	*Erythrina* spp. *Leucaena leucocephala* *Sesbania* spp.	
Tree-Crop-Livestock Mix around Homestead (known as Home Gardens, these associations are found in almost all ecological regions and several countries; only some examples are given)	South and SE Asia (Humid lowlands)	Fruit trees and some plantation crops mentioned under Agro-silvicultural systems	e.g. Home Gardens of Java (Wiersum, 1982)
	Nigeria (Humid lowlands)	*Cola acuminata* *Garcinia kola* *Irvingia gabonensis* *Pterocarpus soyauxii* *Treculia africana*	
	Latin American countries	Several species mentioned under Agrosilvicultural systems	Wilken (1978)
	Tanzania (Highlands)	*Albizia* spp. *Cordia africana* *Morus alba* *Trema guineensis*	Chagga Home-gardens (Fernandes et al., 1984)

TABLE 3. THE ROLE OF WOODY PERENNIALS, THEIR ARRANGEMENT AND INTERACTION WITH OTHER COMPONENTS IN SOME COMMON AGROFORESTRY SYSTEMS

Systems	Sub-systems/ Practices	Primary role of woody perennials	Arrangement of components	Nature of interaction between major components
Agrosilvicultural	Hedgerow intercropping (Alley cropping)	Protective (soil productivity)	Zonal	Spatial
	Improved fallow	Protective (soil productivity and productive)	Zonal	Temporal
	Multistorey crop combination	Productive	Mixed	Spatial and temporal
	Multipurpose trees on farmlands	Productive	Mixed	Spatial
	Shade trees for commercial plantation crops	Protective and productive	Mixed or zonal	Spatial and temporal
	AF fuelwood production	Productive	Zonal	Temporal and spatial
	Shelterbelts and windbreaks	Protective	Zonal	Spatial

TABLE 3. CONT'D

Systems	Sub-systems/ Practices	Primary role of woody perennials	Arrangement of components	Nature of interaction between major components
Silvopastora	Protein bank	Productive (and protective)	Zonal	Temporal
	Living fence	Protective	Zonal	Spatial
	Trees over pastures	Productive (and protective)	Mixed and zonal	Spatial
Agrosilvopastoral	Woody hedgerows for browse, mulch, green manure and soil conservation	Productive and protective	Mixed	Temporal and spatial
	Tree-crop-livestock mix around homesteads	Protective and protective	Mixed	Spatial and temporal
	Agrosilvicultural to silvopastoral	Productive	Mixed	Temporal and spatial