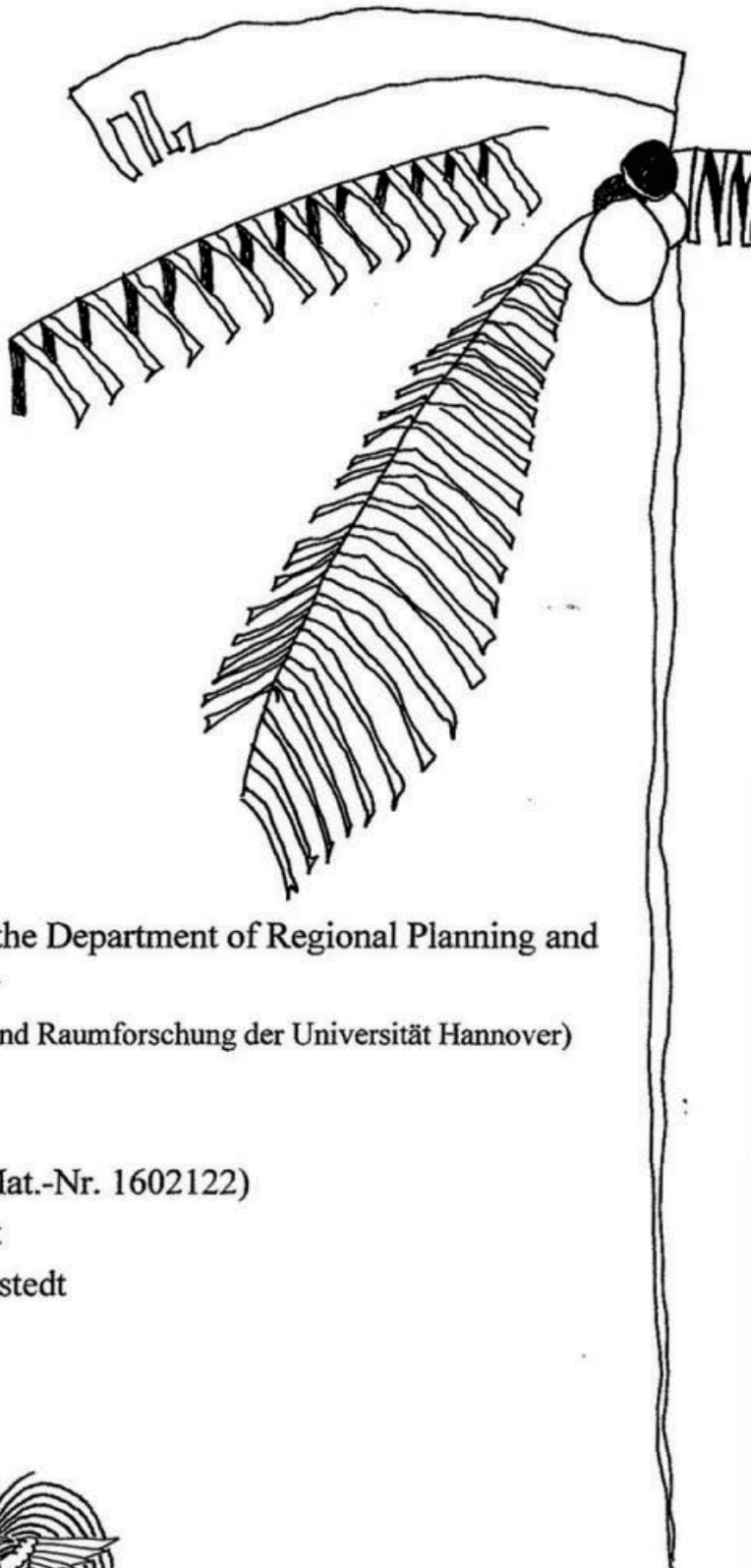
DEVELOPMENT CONCEPT OF AN APPROPRIATE AND SUSTAINABLE AGROFORESTRY SYSTEM FOR SUBSISTENCE FARMERS IN GURAKOR

A case study in Papua New Guinea



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Foreword

During my first stay in PNG as a student doing a period of practical training in the HDC in Bundun I had insight into subsistence agriculture with shifting cultivation and also into permanent organic farming which has already been practised since 1982 in the HDC where only a restricted piece of land is available to produce food and firewood for the workstaff and the groups and guests who stay in the HDC for seminars, courses, recreation, etc.

A pilot project was just started in 1996 in the close vicinity of the HDC. As a result of two 'Law and Order Awareness Seminars' and two 'Youth Development Seminars' at the HDC the idea of Local Village Development Training Centres or in PNG Pidgin English 'Asples Trening Senta' (=ATS) was born. The goal of such training centres was to generate cash income for all unemployed rural drop-outs, to cut out the major root of rural crime, and to create a counter weight to urban migration by making use of the available land resource through sustainable organic farming and animal husbandry (BERGMANN 1997, 1, unpub.).

Faced with those and other rising problems, like land degradation, insufficiency of agricultural production and increasing demand for food and cash, I felt the challenge to try and transfer my Middle European knowledge and experiences in landscape planning to totally different conditions such as natural environment, society, language and culture in PNG. I set up the goal to analyse the situation of a village, which is situated in close vicinity to the ATS to show economic, ecological and socio-cultural needs, problems and opportunities on a local level and thus provide a basis to develop a sustainable agroforestry system (=AFS) appropriate to the given situation. The 'sector' agroforestry was chosen as it still represents the most important but neglected economic 'sector' in PNG and because the development of farming and household systems provides an enormous ecological potential for the protection of natural resources and economic potentials like increases in income.

I hope that this thesis can contribute to the rising of awareness and to a wider support for Local Training Centres, like the pilot project in Bundun, since other regions surely face very similar problems as the village described in this thesis. To speed up implementation grants from the government, non-governmental organizations (=NGOs) or business firms will be required for the setting up of the facilities (cf. BERGMANN 1997, 11, unpub.). Being based on national and international manifested aims and strategies for sustainable development, this thesis could help to tap directly or indirectly (e.g. through NGOs or aid programmes) financial help. For instance, on the basis of the Lomé Conventions and the Green Paper of the European Community (EC), micro-projects or environmental education that is more relevant to local economic conditions, for sustainable agriculture and rural development in the developing African Caribbean and Pacific countries (=ACP) can be supported (cf. EU 1997, 69pp). Relieve is given to NGOs that also assist activities designed to raise public awareness, and the environment budget line of the EC supports innovative pilot projects covering environmental cooperation in ACP countries (cf. EU 1997, 122). Further severe famines in 1997/98 through 'century' draughts caused by El Niño hopefully have brought special attention and better support to Pacific food security and the need for improved agroforestry.

List of contents

List of figures

List of tables

List of boxes

List of maps

1 INTRODUCTION

1.1 Inducement of the project

1.1.1 Problems and policies in Papua New Guinean subsistence agriculture

First some problems and policies in subsistence agriculture of Papua New Guinea (=PNG) are shown to place the area of concern, the village Gurakor, in a wider context and give an introduction into the situation in this country.

During the next years, PNG's **growing population** will demand improved standards of living and will place great pressures on its land resources. PNG had a population of only 2 million people in 1966 on 462.840km^2 of rugged land. Until 1990 the population almost doubled to 3.9 million and is conservatively predicted to reach 5 million by 2005 and 6.6 million by 2015 (ALLEN 1996). The Morobe Province, with a total population of 380117 in 1990, which is 10.1% of the population of all 19 provinces in PNG, is one of the most affected provinces in PNG concerning population growth (cf. RANNELLS 1995, 142). In this province where Gurakor is situated the population density reaches 11 people per km^2 while in the whole of PNG it is 8 on average. PNG has still the lowest population density in the Southeast Asian region (e.g. Indonesia has 97 persons per km^2) but during the 1990-2010 period PNG is expected to lead the rate of 38% average population growth in the Southeast Asian and Pacific region with 51% only behind Laos (CONCEPCION 1993, 33pp).

If these extra people are to be adequately fed and their **cash needs** met, **food production** will have to be **increased**. About 3.1 million of the present 3.9 million people in PNG are feeding and housing themselves and are selling crops for cash from their own land with their own labour (ALLEN 1996). It is not frivolous for people to want some things that only money can buy, like clothing, radios, travel and imported food, in particular rice, tinned fish and meat. It is also clear that where cash incomes are higher, the health and education of children and adults is usually better than where cash incomes remain low. Thus each year approximately 200.000 ha of forest, regrowth, or grassland are cleared for village-based food and cash crop production in PNG (FREYNE, McALPINE 1987). In general, observational and land experimental evidence indicates that the deleterious effects of clearing are minimized under traditional clearing practices combined with relatively low levels of land-use intensity. There are, however, causes for concern that the maintenance of traditional clearing practices and the simple adaption of them may not be sufficient to meet the changes in land use that will inevitably accompany future developments within the country. The requirement for increased food and cash crop production is being met by intensifying the use of existing areas, which means that the fallow length is reduced. This is in many regions leading to **land degradation** and, as archaeological and ecological evidence in PNG indicates, permanent **conversion to low productivity grassland.** This can occur already at relatively low levels of population density due to the poor soil conditions prevalent in the largest areas of currently unused land in PNG. Today, at least 11 % of the

once cultivated land is covered by grassland (cf. ALLEN, BOURKE 1997, 2) which are virtually unused except for burning for hunting, a practice that prevents the possible regeneration of shrubs and woody species. As population growth has brought problems of land shortages to subsistence farmers, besides the shortening of fallow periods and land degradation, all over PNG forests are moving further away up the sides of mountains. The shifting cultivation with slashing and burning needs more and more land, **destroys the forests** and as a result the **topsoil washes** away (cf. GOELTEN. 1990, foreword).

While intensified land use resulting from the introduction of perennial cash crops is widely perceived and documented, that associated with a larger subsistence food-production component has not yet been sufficiently recorded. In PNG, emphasis in agriculture has moved towards the production of cash crops, accounting for 45% of the country's total export income. On the other hand, food imports typically absorb 60-75 % of the value of earnings from tree crop exports and the **food self sufficiency** of the country has further **decreased** in the last decade (cf. FERRAR, PERSLEY 1987, 84). In 1980, already 21% of PNG total imports fell to food stuff (WELTBANK 1997, 274), rice, other cereals and cheap canned food with meat and fish being the main lots. As cereals now provide about 25 % of the average Papua New Guineans' minimum daily energy requirements, the imported rice has substantially reduced the demand for domestic staples. In the highlands and other areas where smallholders have increasingly participated in the cash economy people may have benefited from increased cash incomes (FERRAR, PERSLEY 1987, 84), but the trend has been decreasing with declining prices on the world market and today the marketing of small-scale farming products is only possible through protectorate policies. The agriculture policies of the PNG government is responsible for the **lack of export and home market oriented diversification** of agricultural production, which has hardly changed since independence in 1975.

The Premier of the Morobe Province Utula U. Samana noted in GOELTEN. (1990, foreword): "Whilst, the Nation grapples with the concerns of the state, namely the running of the bureaucracy, and investments involving high finance and trade in need of cash, the villagers grapple with the basic needs of the family - food and shelter. Yet, when one, assesses the imports of basic food items, canned or otherwise, one wonders what the Government's planning is up to, and where the priorities lie. Subsistence agriculture gets the least attention, or none at all by Government agricultural extension services."

1.1.2 Study objectives and considerations

Facing the problems described above the main purpose of this thesis was to provide local evidence for the necessity to develop sustainable and appropriate agroforestry systems (=AFS) for subsistence farmers in the sense of an holistic approach. It was the aim to work out the potentials and constraints of the present AFS on a special example - the village Gurakor and then to develop ideas and proposals, which could for instance be used for extension services either by

governmental or non-governmental organisations (=NGOs). Although the implementation of the concept and the testing of improved techniques could not be carried out within the scope of this thesis, field work should not only provide a basis of information and incorporate local knowledge, during the stage of field work also awareness of local problems should be raised among the villagers. Farmers themselves should take part in the process of finding appropriate techniques and they should be motivated to improve their own situation, rather than confronting people with ready solutions. Therefore it has been tried to generate interest and confidence in the Local Training Centre in Bundun. To change people's attitudes and behaviour toward sustainable land uses can be a long lasting process and must be part of following projects and initiatives.

The results of this thesis should provide a guideline for the development and hints for the implementation of sustainable and appropriate farming system (=FS) in Gurakor but also in villages under similar circumstances. Further, the results of this diploma paper could serve as a basis of discussions and seminars which are frequently held in the HDC in Bundun and should serve to raise public awareness for the agroforestry 'sector', which is still neglected not only by government services but also by NGOs or to apply for more effective support, governmental or other in the development of sustainable and appropriate agroforestry (=AF) in PNG. Particularly the aim to reach wider support of local training centres for rural development such as the pilot project 'Asples Trening Senta' (=ATS) in Bundun was a main cause for this study.

The study's goal for sustainable farming is not only a wish to maintain an ecological equilibrium it is also an economy necessity because subsistence farmers rely on their environment for their daily livelihood and because they have few alternative sources of income should the system degrade. Under the conditions of rapid population growth and increased demands for cash, what are the chances that PNG land managers will be able to create sustainable farming systems? Facing the manifold problems described above, it is clear that only an integrated approach, including socio-cultural, economic and ecological aspects can provide possible solutions.

BOX 1: What is Agroforestry ?

When speaking about AF it is often overseen that AF can be seen as an idea of the potential improvements of this cultivation practice, but also as the practices and the techniques which are applied at the moment. Both interpretations vary widely in between planners themselves and among land users. In this thesis the term AF is used according to the generalized definition of Lundgren and Raintree (1983, 2):

"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 AFSs there are both ecological and economical interactions between the different components."

Thus traditional shifting cultivation systems are already AFSs as they include perennials in the period of the cultivation cycle during long lasting fallow, but also during the cropping cycle when fruit- and nut trees are deliberately protected or planted!

1.1.3 Gurakor – a short biogeography and demarcation

The village Gurakor in Papua New Guinea

Fig. 1: The village Gurakor in Papua New Guinea. A+B: Maps of PNG (modified according to MURRAY, WHEELER 1993, 9, 12p), C: Topographic map of the Wampit fault (part of RASC 1981), D: Drawing of Gurakor's surrounding. ⇛

Apart from some smaller islands, PNG occupies the eastern end of the island New Guinea which is, after Greenland, the world's largest island. It stands on the Sahul Shelf, a submarine extension of the Australian continent a few degrees south of the equator (cf. fig. 1A). There is still a very limited network of roads around the country and no road at all between Port Moresby, the capital of PNG on the main island and the North coast (cf. fig. 1B). Therefore people from overseas that arrive at the international airport in the capital will have to get another flight to Lae, the port and district headquarter of the Morobe Province, where the study area is located. As Public Motor Vehicles (=PMV) run very irregularly and are not directly available at Natzab Airport on the outskirts of Lae, it is necessary to arrange a private lift to Gurakor. This small inland village lying approximately 60 km away from Lae can be reached after an hour's drive on the Lae–Bulolo highway, a sealed road, which follows the Markham River and later the smaller Wampit River that flows to join the huge Markham (cf. fig. 1C). When driving some more 15 km along this road in the direction of the Wau-Bulolo goldfields, one reaches the sub-district station Mumeng to which Gurakor belongs to from an administratory point of view.

Fig. 2 shows that Gurakor is physiographically located in the Wampit Fault, the northern end of the large Owen Stanley Range which forms the mountain spine of the Papuan mainland.

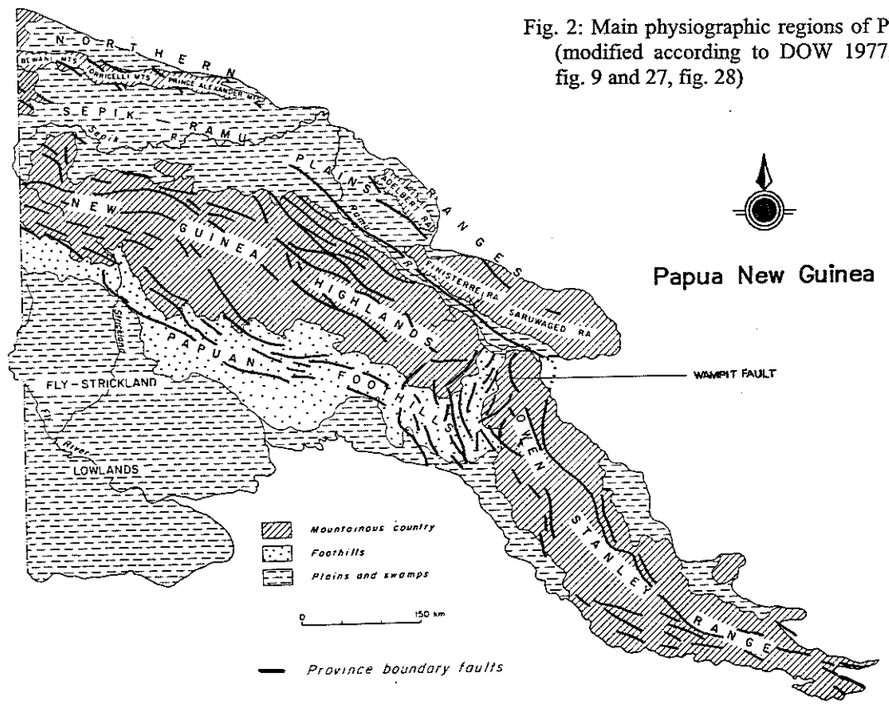

Fig. 2: Main physiographic regions of PNG (modified according to DOW 1977, 4, fig. 9 and 27, fig. 28)

The village Gurakor in Papua New Giunea

Fig. 1

A+B
Maps of PNG (modified according to MURRAY, WHEELER 1993, 9, 12p)

C
Topographic map of the Wampit fault (part of RASC 1981)

Scale 1: 250000

D
Drawing of Gurakor´s surrounding

ELEVATIONS IN METRES

DEPTHS IN METRES

PRINTED BY THE ROYAL AUSTRALIAN SURVEY CORPS DEC 1981
DEF/ARMY/9814

Papua New Guinea

Development Concept of an Appropriate and Sustainable Agroforestry System for Subsistence Farmers in Gurakor

Map n° 1

Map of site and topography

Legend

- < 400 m
- > 400 m - 600 m
- > 600 m - 800 m
- > 800 m - 1 000 m
- > 1 000 m - 1 200 m
- > 1 200 m - 1 400 m
- > 1 400 m - 1 600 m
- > 1 600 m
- rivers and creeks
- main road (sealed)
- demarcation line of the study area

Scale 1:50 000

N

S

Modified enlargement of topografic map (RASC 1983)

Diplomarbeit
Institut für Landesplanung und Raumforschung
Hannover 1998
Prof. Dr. Dieter Fürst und
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Although the Wampit Fault is part of the Mobile Belt, which has been deformed periodically since at least the late Mesozoic and has therefore been an unsettled sedimentary environment (DOW 1977), the area of and around Gurakor has only little earthquakes and no ash fall today. Due to the rugged geography of PNG with mountain towers and rushing rivers, a variety of cultures and languages has developed itself and like any other community in PNG, the villagers of Gurakor share their own language, 'Keyang', with only a handful of other villages as well as traditions they only have in common with these allied neighbour tribes.

As Gurakor lies about 550m above sea level, only 6 degree 50 minutes latitude south of the centroid and 146 degree and 38 minutes east longitude it is dominated by characteristic tropical weather which is warm and humid throughout most of the year and differs only between rainy and a usually short dry season. In the valley gentle slopes and plateaus falling into the Gurakor Creek to the West and further to the Wampit River, are considerably used for gardening (cf. fig. 1D). In the east, the land rises to a prominent range of mountains up to 2752 m (Mt Shungol) with precipitous deeply dissected flanks and with a system of small and large streams, creeks and some impressive waterfalls. Large proportions of these steep mountain slopes are still covered by dense mostly primary rainforests which bring about a fascinating variety on plants and animals. Mountains on the opposite side are settled cultivated by the neighbour villages Omala and Bupu.

Demarcation of the study area

The village's demarcation line is not yet defined properly through the land court and large pieces of Gurakor's land are allowed to be used by other villages since christianization. Therefore a demarcation line for the study area was defined which was orientated on natural and land use borders (cf. map N°1). In the south the small creek 'Dembake' separates Gurakor from the Lutheran Church's ground with the HDC and ATS, which is let on lease by Gurakor, whereas 'Wara Lupko' (=Wampit River) defines the western border of the planning unit. The mountain ridge to the east, be hind of which clear borders are even for Gurakor's elders hard to describe, (Muwapu kil) is taken as a rough demarcation continuing in an imaginative line, described by villagers, through the cemetery that is used together with the neighbour village Timini and presents a border mark for land use in the north. These borders may approximately separate present land use units of the neighbouring villages Omala, Timini, and Bundun but do by no means represent any demarcations of land ownership.

1.1.4 Procedure and methods

Fig. 3 shows the methods and procedures applied during the different planning stages and field work, but in practice there where no clear boundaries between these different stages and target setting and evaluation stages took place on site and in Germany as explained below.

Phase I. Prediagnostic and target-setting stage

During a first stay in PNG at the HDC doing a practical in winter 1996/97 it has been possible to get a good insight into tropical agriculture, site-staple organic farming at the HDC and the

adjacent ATS, and an general view of socio-economic conditions and politics in PNG. An important prerequisite for field work in PNG was to learn the common linking language, known as Neo-Melanesian, but more frequently just as PNGn Pidgin English.

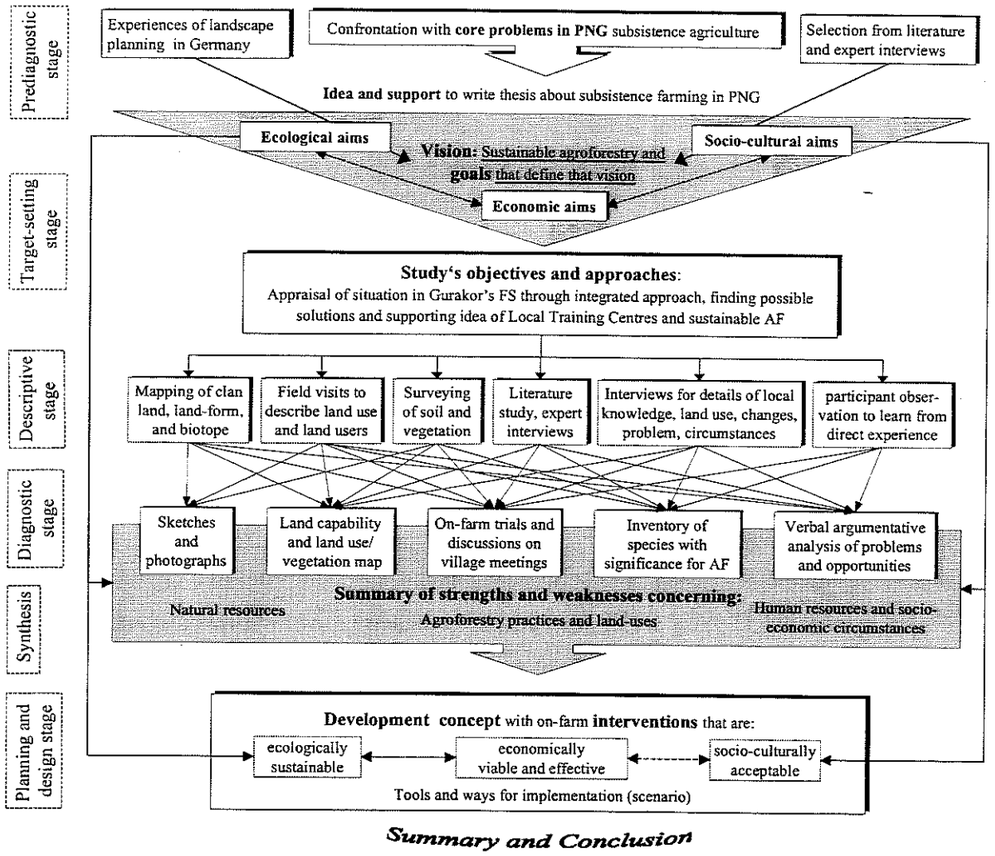


Fig. 3: Procedure and methods

At the end of the practical in Bundun, the idea of writing a thesis about appropriate sustainable development in tropical agriculture came up, and objectives and aims for a thesis had to be put into concrete forms. After contacting Prof. Dr. D. Fürst who supported the idea to write this thesis, a return to Germany was not necessary anymore. Applying and waiting in Australia for another visa for PNG, existing published literature was reviewed at universities and more detailed information about PNG, tropical agriculture and AF was gathered. Especially at the Research School of Pacific Studies, Canberra and the Commonwealth Scientific and Industrial Research Organization (=CSIRO) in Brisbane key experts on PNG–studies provided useful information. Back in PNG and the HDC the village Gurakor was chosen for its close proximity to the HDC. Before starting field studies (from Mai-August 1997) the studies' intention was explained during

to make field work in the village and to achieve assistance and involvement of the village inhabitants.

Goals for the field study in PNG were already formulated in the stage of 'preparation in advance' whereas more detailed sub-targets arose out of the site conditions and current problems of the village which made an integrated approach necessary. A list was set up concerning the kind of basic information and surveys to be used according to priority goals and the restricted period of time and appropriate methods were selected. Facing the situation in a developing country, it was clear that only general official or written information on a national or regional level and even less on a local basis would be available, to say nothing of the farm or household level, so that information gathering had to be pragmatic and spot checks, field visits and interviews had to be carried out to get qualitative information rather than quantitative proved data.

Phase II. Diagnostic and descriptive stage

Prior to field work a selection from literature and planning units[1] of the PNG Resource Information System (=PNGRIS) was made to get an overview of the subsistence society as well as physical and environmental conditions of PNG and the area of concern. First it seemed that current information systems like PNGRIS or the 'Mapping Papua New Guinea Farming Systems Project' (=MASP) (cf. ANONYMUS 1997) could apply useful information, but data were very general or not investigated for Gurakor yet. As farming systems in PNG extremely vary according to physical and social diversity, most of the data had to be investigated through extensive field work. Therefore some spot checks on soil type and quality, the most important and restricting parameter for AF, were carried out and other nature potentials such as climate, water resources, species and biotope, as well as the socio-economic context of the village were roughly investigated. Therefore different methods like farming systems research (=FSR), land evaluation or diagnosis and design methods were applied (cf. chap. 1.2.3).

Mapping

During the initial planning phase some general field visits were made to describe the landscape, land use and inhabitants as well as the structure of the settlements. Owing to the lack of maps it was helpful to get an overview, fixed by photographs, from a mountain opposite to Gurakor and later from a helicopter. Under use of these photographs and with the assistance of several clan members (esp. John, Jaling, Tobias, Nikodem) borders of fields that are assigned to the different clans and groups were set on a map (enlargement of the most detailed topographical map, scale 1:100 000, that was available). The name of each locality was recorded, as long as villagers could still remember them, and covering vegetation, human use and particularly the coarse boundaries between primary forest and cultivated land were noted and located on the base map.

[1] PNGRIS is based on few bio-physical evaluations that were in some cases made by soil survey organisations but very few is available for the Morobe province and nothing at all for Gurakor and its surrounding lands.

Monitoring of the basic farming system

The main focus during field studies was to describe the FS in Gurakor such as fallow type and period, cultivation intensity, staple and supplementary crops, other useful plants, garden and crop segregation and soil fertility maintenance techniques. This was done in close collaboration with the farmers and in the role of a learner during the investigation process, in order to learn about the farmers' problems and their efforts to solve them. This was a basic principle of the methodological approach, and a prerequisite for building upon the knowledge and skills of the farmers in developing intensification techniques appropriate to their particular socio-economic situations and cultural background. Following these considerations different types of interview and observation were chosen, which are described in appendix (=app.) 1.

Investigations concerning soil productivity

Other field methods were focused on the evaluation of the soil potential to get more detailed and actual information or at least to verify the information on soil the groups that are described by PNGRIS for three different Resource Mapping Units (=RMU) 224, 245, 384, which are of part located on Gurakor's land. First an attempt has been made to ***investigate yields*** of different staple crops in relation to location and cropping methods. However, productivity measurements proved to be very difficult in Gurakor due to the complex nature of its mixed gardens, the many local varieties of crop species and the irregular and individual harvesting of different crops. Thus, exact measurements were not possible in a short period of time and the extreme droughts caused by 'El Niño', leading to disastrous harvest losses, made any further yield measurements pointless. Still it was a good exercise to come to know the farming system, compare the yields in areas of different land-use intensity and with products on local markets or on garden plots of the HDC and then to discuss these experiences with the farmers.

Further three spot checks to analyse ***soil profiles*** according to the US Soil Taxonomy were made. The US soil system was chosen because it is also applied by PNGRIS and other soil studies of Australian scientists in PNG. It is the most logic and detailed system for worldwide use at the present but its classification of soil groups is often only possible after accurate laboratory tests[2]. Because those analyses were impossible even at the University of Technology in Lae and no soil classification key was available, the US soil taxonomy proved to be inappropriate for field work in PNG. As a consequence, it was not possible to identify the different soil types distinctively and a German clasification key, 'Bodenkundliche Kartieranleitung'[3], was applied, at least to analyse the different soil layers (cf. app. 2). Being back in Germany, Soil Scientist TRÜBY (1998), University of Freiburg, explained that those methods cannot be transferred to tropical conditions, as, for instance, other kinds of clay minerals would exist with totally different properties than in temperate climates. The surveys are therefore highly questionable as possibly errors arose from difficulties in interpretation, inappropriate classification key and instrumental problems. Thus most information on soil groups had to be derived from PNGRIS which, however, is also questionable and very general being carried out on a map base of 1:500.000 and based on interpretation of aerial photographs besides very few soil samples in PNG.

[2] For example, to distinguish Ultisols and Alfisols, which are, according to PNGRIS, present in Gurakor, at least, base-saturation has to be determined.

[3] a copy of which was provided by Ute Engelberg, Dipl. Ing. Agriculture, who has used the German soil classification key in Madang, PNG, for her doctoral thesis.

Phase III: Diagnostic stage

Considering all the gathered information, strengths and weaknesses of the natural (abiotic and biotic) and human resources had to be worked out and the FS was analysed how and how well it worked. Therefore singular land use practices and finally the whole system were evaluated for their sustainability. Of course an evaluation was already made on site, based on experiences in German landscape planning (such as evaluation of nature potentials, general definitions of sustainable and appropriate development) and intuitively through confrontation with the obvious problems and needs. Interviews or discussions with villagers, individually or in village meetings, presented evaluations from their own point of view.

Back in Germany the evaluation was placed in a wider context and based on international and national accepted goals and criteria of sustainable agriculture or AF, as in the outcomes of the Rio Conference, its follow up process, and the National Sustainable Development Strategies for PNG[4] (cf. chap. 1.2). Therefore a review of literature and topical information from the internet helped to complete goals and strategies for sustainable AF and to find appropriate evaluation methods. As most evaluation methods did not meet the manifold aspects of sustainable development on a local scale or the conditions in a tropical developing country, a selection of different components was made (cf. chap. 1.2.3).

According to the complex nature of the topic with socio-cultural, ecological and economic aspects and the restricted data base, it appeared to be most appropriate to evaluate most important potentials by verbal reasoning rather than by calculative models. A complete assessment of the potential of species and biotope in a diversified tropical ecosystem would have been too complex and extensive as to be described and discussed comprehensively. Therefore only some important service functions, the cultural and socio-economic benefits of species and biotope were described with special focus on AF and subsistence needs. In many other cases local data were lacking and only general statements were possible.

For the evaluation of the production potential of soils it was first tried to apply simplified calculative evaluation methods of BASTIAN, SCHREIBER (1994) that are practised in Germany. However, this proved to be neither possible due to the lack of a reliable database, nor transferable due to the differentiating circumstances in a tropical environment. The following excursus in box 2 will show this.

[4] the outcome of the 20th Waigani Seminar in Port Moresby, PNG in Aug. 22-27, 1993

BOX 2: Problems with evaluation of soil erosion

Besides difficulties in soil sampling, that were described above, the method of BASTIAN, SCHREIBER (1994) is inappropriate to evaluate soil erosion, as it uses the average rainfall during summer (=R-factor) as indicator of rainfall erosivity and thus does not meet the seasonal variability of rainfall in PNG and the erosive potential of individual tropical rainstorms with a much greater energy load. Although a theoretically good approximation was made by BELLAMY, writing in 1995 for PNGRIS, to assess the erosive potential of PNG rainfall and its seasonal variability, the results seem to be inaccurate, as they are based on a very limited amount of continuous rainfall data (cf. BELLAMY 1995, 1pp). Statements of locals as well as surveys by McALPINE et al. (1975) in Gurakor were controversial to data on total and monthly rainfall provided by PNGRIS. Besides, the striking thing is that PNGRIS investigates rainfall erosivity and soil erodibility as separate factors, and does not include the factor slope as an important component to calculate sensibility to erosion as a whole function. Likewise the Food and Agriculture Organization's (=FAO) 'framework for land evaluation' is inadequate as it focuses on the suitability of the land for a given crop, but does not take into account the risk factor or the vulnerability of soils to damage.

Thus it was necessary to improvise and simplify evaluations but always with criteria for sustainable AF in mind.

Phase IV: Design and planning stage

Development of a concept with aims and different measures

The next step was to find out how the FS could be improved and then to set up proposals and ideas for sustainable and appropriate AF development for subsistence farmers in Gurakor. Based on national and international goals and strategies, the summary of strengths and weaknesses in Gurakor's AFS as well as reports and experiences of organic farming practices in Bundun or other places, first objectives were deduced and then interventions and measures for sustainable and appropriate AF were developed. A testing of measures for improvement in AF in the village was not possible within the scope of this diploma paper, but expert interviews and experiences in Bundun and ATS were helpful to determine the success or failure of other attempts to introduce improvements in AF.

Finding strategies and tools for implementation

Finally the question was what could be done to develop and disseminate improved technologies. Again based on national and international aims and strategies that were set up in the introductory part of this thesis, tools for implementing sustainable and appropriate AF practices in the village Gurakor were selected. Additionally available support systems that could create opportunities for improved AF and provide conditions conductive to the adaption of technologies were looked for and described. To visualize future options for the village two scenarios were compiled.

1.2 Sustainable agroforestry – from Rio to Gurakor

1.2.1 From international to national aims and strategies

In many developing countries food shortages and environmental degradation of the resource base are present or problems arose from the 'Green revolution' that counted on external inputs to reach short term maximization of yields but did not adequately focus on long term effects and environmental issues. Those and other twin problems of economic development and environmental degradation have led to scientific recognition that the earth's natural systems supporting life have their limits not only on a local or regional but also on a global scale. As a consequence, the idea of an integrated concept of sustainable development was designed that would integrate economic, environmental and social aspects of development, introduced in 1987 by the so called Brundtland report of the World Commission on Environment and Development (=WCED). In June 1992, this report was followed by international agreements of the United Nations Conference on Environment and Development (=UNCED). This Earth Summit in Rio de Janeiro, which PNG also joined, called for a global commitment to the implementation of measures for achieving sustainable development manifested in the Rio Declaration on Environment and Development (=RDED)[5], Agenda 21[6], the Convention on Biological Diversity (=CBD), the Forest Principles (=FP) and the Framework Convention on Climate Change (=CCC). As a consequence of these international agreements, also agriculture or AF must meet the principles of sustainable development as defined by FAO (cf. box 3) and later implied in Agenda 21.

BOX 3: What is sustainable agriculture?

"Sustainable development is the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable." (FAO 1994, 5)

Although the meaning of this definition can be generally understood it is very vague in some aspects. For example, it is not clear what is meant by "basic needs" or whether all animal and plant species have to be preserved even if they are without a known use or value to present or future generations. Further, it is hardly possible to define explicitly, what human needs are today and will be for future generations. Although a prescriptive rule about these and many other issues cannot be derived from this definition, the concept of sustainable development can be

[5] a nonbinding series of principles on sustainable development, that are understood to be a description of norms that should lead national behaviour in the future (BROWN, LEMONS 1995, 3)

[6] an international compromise for action in the 21st century with 40 chapters focussed on solving the twin problems of environmental protection and economic development (cf. ibid.)

understood as interpreted by provisions of Agenda 21 and other Rio documents, supplemented by its follow up process. This surely not complete international compromise in Rio will be used in this thesis as an operational basis for goals of sustainable AF development and as criteria to evaluate the current FS in Gurakor.

Further guidelines are derived from national goals of PNG. Since PNG has accepted its common responsibility to the environment in Rio, it embarked on an official programme of producing its own Agenda 21- the National Sustainable Development Strategy (=NSDS). Therefore, a seminar on Environment and Development commences, the 20th Waigani Seminar, was held in Port Moresby on August 22-27[7] with a provisory NSDS as the outcome, which will just be called NSDS in the following text. The need for sustainable development is further legitimized through the five goals of the Preamble of the Constitution of the Independent State of PNG (=CPNG-P) that covers integral human development, equality and participation, national sovereignty and self-reliance, 'PNG ways' and, as the fourth goal states, the conservation and use of PNG's natural resources and environment for the collective benefit of all, and their replenishment for the benefit of future generations (CPNG-P).

1.2.2 Different objectives and strategies towards sustainable agroforestry

In this chapter the objectives and strategies that are relevant for AF planning on a local level will be described with the main emphasis being put on land cultivation techniques. The following analysis will show social, economic and ecological aims and requirements which then have to be equally integrated in the development concept to make it ecologically sound, economically viable and socially responsible (cf. Agenda 21, 3.2). Different aspects neither can nor shall be absolutely distinguished because the past has shown that separating economic development problems from environmental issues is futile[8] since both issues are interrelated and interdependent.

The two following principles have to underlie all ecological, economic and socio-cultural aspects and should be kept in mind through the following exposition of sub-targets:

- **Intragenerational equity**: Sustainable development has to decrease disparities in standards of living and has to ensure equal opportunities for all people on a local, regional and global scale (RDED, prin. 5; CPNG-P, 2nd+4thgoal; FAO 1994, 5).
- **Intergenerational equity**/stewardship: The current generation should not leave an impoverished environment for the next generation (RDED, prin. 3; CPNG-P, 4thgoal; FAO 1994, 5).

To give an overview about all aims and strategies that shall be the basis for sustainable AF development in Gurakor they are summarized in table 1.

[7] The invitation to this seminar was explicitly extended to all persons, whether politicians, government officers, persons from the private sector, NGOs, other groups and all grassroots organizations to attend and contribute.

[8] E.g. development in AF cannot degrade environment, especially the production potential of the soil, without undermining its inherent economic development (cf. KOLLEGE 1996, 650).

SUSTAINABLE AGROFORESTRY FOR SUBSISTENCE FARMERS IN GURAKOR		
	Aims	**Strategies**
Ecological criteria	• Preserve, increase or restore productivity of land in areas under cultivation [a] and soil functions of regulation [a] • Control degradation, erosion and mass movement [a] • Safeguard groundwater and surface water quality and quantity [a+d+i] • Protect biodiversity and sustainable use of biological resources and their components [a+b+d+n+p] • Maintain equilibrium of climate and promote non-generative resources [a+c fao]	• Promote integrated (appropriate alternative [o]) farming practices (integrated fertilization and pest management) [a] • Improve management of inputs [a] through effective use of local resources (soil, water, wastes, genetic resources, AF) [a+n] • Diversify cropping and production systems [a] • Develop methods to control runoff, evaporation [a+o], soil erosion, mass movement, degradation [a] and safeguard water purification [o] • Sustainably manage and protect forests, their resources and functions [a+f] esp. in mountainous and water catchment areas [a] • Avoid introduction of and/or control non-indigenous species [a+b] • Promote and tap a greater array of indigenous plant and animal genetic recourses instead, like well adapted traditional species/varieties in agriculture [a+b] • Promote renewable energy and other resources (wood/ biogas)[a+n+f] Recognize, enhance and promote AF [a+ f+n]
Economic criteria	• Satisfy basic material needs (quality and quantity of food, drinking water, firewood, medicine, materials, etc.) [a+d+n] • Promote better self-sufficiency/ self reliance [a+n+p] • Ensure economic stability and resilience of the system [a+d] • Offer opportunities for economic development and eradicate poverty [a+c+n]	• Intensify and diversify farming systems (AF) [a] • Use site stable technologies and crops [o] • Promote efficient use of indigenous resources (knowledge!) and low input technologies, and minimize external inputs [a] • Support small scale systems for subsistence market [n] • Enhance subsistence production, and possibilities for small scale business and surplus production [a+n] • Improve and promote storing and marketing infrastructure [a] • Develop adaptable and diversified structures [a] • Balance seasonal labour-peaks [o] • Promote equal and appropriate education [n]
Socio-cultural criteria	• Human beings as the centre of sustainable development [b+d+o] • Promote and develop human resources [a+n] • Promote social justice and intergenerational and intragenerational equity [a+d+n+p] • Ensure healthy life in intact environment [a+d+c] (clean drinking water [a+n], sufficient and healthy food [a+fao], basic medical care [a]) • Satisfy immaterial basic needs and a productive life[o-d] (higher level social and cultural necessities and contentment [o])	• Promote participation, cooperation and information and better linkages of all affected people [a+n] • Strengthen/ participate underprivileged groups [a+n] • Tap and promote traditional knowledge [a+n] • Ensure equal possibilities for education and training [a-n] • Maintain or promote self-reliance [a+n+p] • Integrate sustainable/ appropriate technologies in AF [a] • Ensure fair access to different resources (land, finances, inputs, markets) [n+ a] • Built on and safeguard local/ PNG's social, cultural, spiritual, and physical resources, and emphasize moral and spiritual duties to conservation = 'PNG ways' [a+n+p] • Serve contentment of personal situation , ensure social contacts, safeguard independent and self-guarded lifestyle a and other immaterial needs [o].

Table 1: Aims and strategies for sustainable agroforestry in Gurakor (cf. [a] Agenda 21, [b] CBD, [c] CCC, [d] RDED, [f] FP, [i] YATSU 1997, [n] NSDS, [p] CPNG-P, [o] own interpretation)

A. Ecological aspects

In a Special Focus Report on Agriculture and the Environment fife years after Rio, YATSU (1997) notes that there are many signals that current agricultural production processes are environmentally destructive and not sustainable and that greater efforts must be made to reduce environmental degradation, improve ground-water management and develop a more sustainable agriculture. As the agro-forestry-fishery industries are directly affected by physical and environmental limitations unlike other industrial sectors, it is most important that a pattern of sustainable agriculture is developed taking into full consideration environmental parameters (YATSU 1997).

Such sustainable management and conservation of land, water, plant and animal genetic resources to safe human needs in such a way that the inherent productive qualities of the natural resource base are preserved for future use, too, has already been stressed in Rio documents 5 years ago (cf. Agenda 21, 14.2, 3+83; RDED, prin. 4; FAO 1994, 5).

Maintenance of the production potential and conservation of surface and ground waters

The major challenges before agriculture, esp. in many developing countries, including PNG, are to increase production on land already in use and to avoid encroachment on land that is only marginally suitable for cultivation (Agenda 21, 14.1), to control soil degradation and restore the productivity of degraded lands (ibid., 14.44), which includes not only the production potential of the soil but also its functions of regulation (e.g. buffering, filtering and transformation). Thereby special emphasis must be laid on management and conservation methods in mountainous areas (ibid., 13.6).

Further quality and quantity of ground and surface water have to be safeguarded to provide clean drinking water for all villagers (NSDS 4B8, Agenda 21, 18.5+36; YATSU 1997).

Strategies

The best means of improving and maintaining the quality and functions of the soil and water is alternative, or at least, as Agenda 21 (14.26+27) claims, integrated farm management and a balanced intensive and extensive agricultural growth through optimal land use. This includes the improved management of inputs through the efficient use of local resources like manure, wastes and by-products to keep harvest losses as low as possible and to ensure that risks to the ecosystem are minimized. Reduced, well evaluated use of agricultural chemicals such as mineral fertilizers and pesticides should be applied if appropriate (Agenda 21, 14.27+74; 19). It has yet to be proven, whether the use of external agrochemicals is socio-economically appropriate and ecologically sustainable at all, e.g. whether it can be practised without affecting water resources (cf. ibid., 14.86; 19).

The sustainable use of biological and ecological processes through AF or other methods of diversification, e.g. crop rotation is seen as an important strategy (ibid., 14.26+27) whereby the efficient and sustainable use of water through appropriate cropping systems could conserve both water and production capacity of the soil.

Measures to prevent soil erosion and degradation especially on cultivated steepland and to restore degraded land, for example through AF (ibid., 11.13) and prevention of progressively clearing of mountain forests (ibid., 11.12; FP), are other important strategies also to prevent impacts on surface- and ground water supplied by the mountainous regions and to maintain an ecological equilibrium (cf. Agenda 21, 13.15).

Protection of biological resources

A primary purpose of the Rio documents (esp. the CBD) is to conserve and sustainably use the diversity of ecosystems, species and genes. This must also be a main focus in AF, because the species we protect today could greatly improve the quality of human life tomorrow. Not only that natural materials are used extensively in industry (like medicines), the local farmers depend on biological resources through food security and in many other aspects for their survival as well. Further biodiversity is a vital resource for crop and livestock improvement so that it has to be promoted in both wild and human-modified habitats (Agenda 21, 14.57+66). As a consequence, forests with their manifold resources and functions (FP, 2b) and, at the same time, AF or agricultural habitats with populations of wild, domesticated or cultivated species have to be conserved or managed in a sustainable way and their components have to be promoted for on-site conservation of plant- and animal-genetic resources (cf. CBD, Art.1+2; NSDS, 4B14; Agenda 21, 14.4, 57, 66 +89).

Strategies

Improved small-scale agriculture instead of making room for large-scale farms, plantations and ranches can help to prevent destruction of most of the remaining habitats for wildlife (FORNO et al. 1996, VII pp). The extension of destructive shifting cultivation practices has to be limited (Agenda 21, 11.13), and with growing population, intensification of AF (aside from population control) is essential if remaining virgin forests are to be saved. However, it cannot be the aim of a sustainable agriculture to introduce high input and monocropping practices in favour of a few high yielding varieties and species with only short term economic gain. Instead, local species and varieties, as well as traditional farming practices have to be integrated or promoted, as far as they are compatible with conservation or sustainable use requirements (CBD, Article (=Art.) 8j+ 10c, Agenda 21, 15.5-6). A greater array of genetic resources has to be tapped and/or protected, for example through sustainable hunting and breeding programmes of local livestock (Agenda 21, 14.26+66) and through protection of rare or unused food crops and other plants, including tree species for AF (ibid., 14.55).

The role of permanent agricultural crops (AF) must be enhanced and advanced, since they are sources of renewable energy and raw material, contribute to the maintenance of ecological processes and set off pressure on forests (FP, 6d). Another strategy for biodiversity conservation is the prevention of alien (non-indigenous) species introductions and the control and eradication of those who threaten ecosystems, habitats and species (CBD Art. 8h). Therefore the use of

indigenous plant material should be preferred in AF, and uncontrolled distribution or introduction of non-indigenous plants and animals must be prevented (Agenda 21, 11.13).

Control of climate and non regenerative resources

This year, people in PNG and many other countries again had to experience how dramatically climatic changes, or irregular perturbations like the El Niño-Southern Oscillation (=ENSO) with extreme droughts, cyclones and in the highlands even frosts, affect natural vegetation, wildlife, agriculture, forestry, human health and economics. AF is not only a victim of global warming, at present, it is also a contributory factor, and in the future it should make a major contribution to reduction of greenhouse gases by the year 2000 as required by FAO (1997), CCC (Art. 2) and Agenda 21 (9.20). Since forests effect the balance of oxygen and carbon in the atmosphere, land use changes that effect the size of tropical forests are a major factor behind the 'greenhouse effect' in the tropics. Large scale slash-and-burn clearing or other forest destruction cause somewhere between 10 and 30 % of global anthropogenic emissions of CO_2 (VOLLMER, SPEIDEL 1997, 12; FAO 1997).

It must also be considered that the destruction of natural forests on a regional scale gives rise to the fear that average rainfall will be reduced and a worsening of agricultural conditions will take place through fluctuations in micro- and meso-climate.

Strategies

To maintain the equilibrium of climate-sensitive gases, appropriate land-use systems have to be promoted (Agenda 21, 9.21). In PNG AF it is therefore necessary to develop more effective cultivation practices without, or at least with reduction of the traditional slash and burn method (cf. Agenda 21, 11.13).

Tropical forests with their vital role to maintain the climatic equilibrium on a local, regional and global level, e.g. as carbon sinks and reservoirs for renewable resources, have to be sustainably managed, protected or enlarged if appropriate (FP 2b+6d, Agenda 21, 9.21). Agricultural systems must be promoted that produce new and renewable environmentally safe and sound energy resources, like firewood or biogas, and more efficiently use those (cf. Agenda 21, 9.11; 14.27+94). Also the NSDS (3+4B) demands, that in particular efforts should be made to plant trees to replace fuel-wood at a rate that is sufficient to meet future energy demands. To provide a buffer against local climate fluctuations, not only forests, but also agricultural systems with greater resilience against climatic changes have to be promoted (Agenda 21, 9.21).

B. Economic aspects

The need for economic development as an indispensable requirement for sustainable development (might be questioned, but) is embodied in Prin. 5 of the RDED. It requires that eradicating poverty has to be an essential task to reduce disparities on world-wide standards of living and to better meet the needs of the majority of the people in the world.

Satisfaction of basic material needs

Satisfying basic material needs is an important social criterion (cf. ibid.; Agenda 21, 1.1) and a presupposition for sustainable development in general, because subsistence farmers are more concerned with lack of secure access to production factors and with their pressing needs for food than with long-term maintenance of productivity. Sufficient production levels of basic necessities like nutritionally adequate food and surplus production for urban centres, regional or international markets (Agenda 21, 14.2), clean drinking water (ibid., 18.65; NSDS, 4B8), fuelwood (NSDS, 3+4B), fibre, medicine (Agenda 21, 6.3) and building material have to be ensured to foster a higher degree of self-sufficiency and self-reliance (cf. CPNG-P, 3rd goal; Agenda 21, 14.16+26; 32.6a). This is particularly necessary since other possibilities of incomes in rural areas remain low and people do not have the purchasing power to buy food when they are in need of it. It is also valid for the national level as the continued dependence on staple food imports is a thread to food security and exports jobs (NSDS, 2).

Strategies

Maintaining and improving the production capacity of land under cultivation must raise food production (Agenda 21, 14.2+3) whereby the security of manifold basic needs such as fuel wood, fibre, medicines, building materials, and other materials aside from food can best be ensured through diversification and integration of agriculture and forestry (Agenda 21, 14.26+27). The efficient use of indigenous resources rather than relying on capital intensive external inputs is a major strategy to enhance self-sufficiency as well as the support of small-scale systems and their agricultural production for the domestic and/or subsistence market (NSDS, 4B12).

Maintaining or promoting of economic stability and system resilience

Economic stability and system resilience are closely connected with the previous aim of the security of basic needs. As experienced during the 'green revolution' and established under 'ecological criteria' above, emphasis on raising productivity can lead to erroneous production methods and irreversible environmental degradation or the neglect of other needs. For example, wood is a commodity that can only be produced in the long term, so that the fuelwood deficit could become even more serious than food shortages (BEETS 1990, 35). Therefore, stability includes a temporal dimension which means that acceptable livelihood conditions and basic needs are not only available for the present, but also for the future (RDED, prin. 1; Agenda 21, 8.2). Already in the shorter term stability of the system has to be safeguarded as it is an important, even life sustaining factor for subsistence farmers. Since they have limited access to resources, technology, alternative livelihood and means of production, there is a high risk that natural resources, including marginal lands will be overexploited (Agenda 21, 32.3).

Strategies

Although often neglected in developing countries, it is 'knowledge' that ensures stable systems. This important resource has to be tapped and/or promoted (cf. Social criteria).

In particular in tropical countries, strategies of diversification are most important to keep the system stable, because the optimal tropical forest is the most diversified systems in the world. Thus, site-stable systems orientated on such an variety must be giver greater support as they are very stable due to their high self-regulation (cf. Agenda 21, 14.25). The merit of the indigenous system, which should be maintained, is that it is based on mainly indigenous trees and crops that are not only familiar and useful to local people but also adapted to local climate and soil conditions and thus less vulnerable (cf. MONTAGNINI 1990, 50p).

To advance economic stability and efficient use of local resources, low input technologies must be promoted and external means of production must be kept at a minimum (Agenda 21, 32.5). This seems to be more sustainable and appropriate than strategies like optimisation of availability of external inputs on a local or national level, that are also advocated by Agenda 21 (14.85)[9].

In the context the international strategy to further open the world market that should lead to economic growth and sustainable development (cf. Agenda 21, 2.9; RDED, prin. 12) must be seen critical. The General Agreement on Tariffs and Trade (=GATT)[10] is currently being negotiated in a shroud of secrecy, almost totally without reference to environment and thus contrary towards demands of Agenda 21 (2.21). Promoting free trade and structural adjustment programmes (=SAPs) will not only have a severe impact on attempts to protect resources but also on the livelihood and social protection of the people in countries like PNG[11].

This point is otherwise not discussed in this thesis as it concentrates on local scale planning. Still it shows that PNG subsistence farmers are no longer independent from international trade policies, although they might have lived in total isolation from government and its services for most of their lives.

Offer opportunities for economic development

Sustainability is a dynamic concept which means that economy not only has to meet the basic traditional needs like food, medicine, bark cloth and many other raw materials from the bush, economy and lifestyle can and must develop to meet population growth and changed conditions in peoples attitudes and needs. Therefore surplus production, rural farm or non-farm employment have to be ensured to alleviate poverty and to guarantee not only self-sufficiency for food and other AF products but also monetary sufficiency to satisfy other needs (cf. Agenda 21, 14.2+26).

[9] Dependence on external resources, like green revolution 'packages' of hybrid seeds, fertilizers and pesticides is not only frequently costly, but also makes the production system in resource-poor environments more vulnerable to external stresses and shocks, such as changes in costs and supply (BARBIER, CONWAY 1990, 36).

[10] coordinating, regulating, pricing, legislating and administrating body that sets the rules for world trade.

[11] A SAP agreement for PNG was signed in 1995 for liberalisation of the economy and structural adjustment. But PNG government was forced to 'postpone' the proposals as nation-wide mass protests claimed that the World Bank and IMF insisted to abolish the 'minimum wage' in PNG, remove price controls on basic necessities, impose 'user pays' fees on health and education, and undermine collective land ownership (LAFANAMA 1997). Moreover, it will further open up the country's forests to rapid development by foreign concerns and unsustainable exploitation.

Strategies

Raising of productivity and funds through more efficient use of indigenous resources, cash crops and diversification of the system have to be accompanied by improvements in storing, reduction of food losses, and rural infrastructure for access to regional and international markets (Agenda 21,14.27). Alternative possibilities of resource use like fish breeding or sustainable hunting must be analysed and identified (Agenda 21, 14.27).

If the intensification of agricultural production is not possible, other possibilities for agricultural or non-agricultural employment or subsistence have to be developed (ibid.). This might include opportunities for economic development in small-scale processing or manufacture of agricultural and other indigenous products, employment in rural service centres, related infrastructural improvements or engagement in eco-tourism (Agenda 21, 14.27, NSDS, 3+4B).

C. Socio-cultural aspects

Human beings as the centre of development

In Prin. 1 of the RDED it is manifested that human beings are the centre of concerns for sustainable development[12]. Since human beings may have different views of such development owing to different values, it also has to be defined out of the local situation and point of view. People have to participate because real sustainability must come from the mind of a person to make a real commitment (cf. Agenda 21, 23.1). Thus the key to attaining sustainable development must be the promotion and development of human resources (ibid., 14.16-20; WCED 1987a, 30).

Prin. 21 of the RDED states that the creativity, ideals and courage of the youth should be mobilised to forge a global partnership in order to achieve sustainable development and ensure a better future for all.

Strategies

Prin. 10 of the RDED therefore proclaims participation of all concerned citizens at the relevant levels (cf. NSDS, 3.3B; 7) and the NSDS (1.5, 2+7) recognizes that bottom-up project planning and linkage of grass-root movements to policy making must be a feature of development planning. Focus on community level activities should use clans as the basic unit and, wherever possible, foster inter-clan participation activities (NSDS, 7.4).

To increase efforts in human capacity building, self-reliance must be promoted through the recognition of the indigenous people's values, traditionally held skills and knowledge in resource use (Agenda 21, 26.3; RDED, prin. 22). Landowner awareness, cooperation, the support of

[12] The RDED and other Rio-documents can therefore be criticised, in that they follow a narrow anthropocentric approach, since firstly human beings must be concerned in discussion on sustainable development and only after that the environment. However, for developing countries it would be hardly possible to put the conservation before development and this approach helps to make the definition of sustainability and evaluations more operational, as it is difficult to make preservation of the natural environment valuable in itself.

innovative information, training and creative education as well as informed decision making are vital in any form of sustainable resource use (Agenda 21, 14.26; 16; NSDS, 4A7.1, 8).

Another strategy is to create better links between all types of researchers, advisors, NGOs, facilitatory and local people and full utilization of trained personnel and available labour in the field (NSDS, 4B15, Agenda 21, 14.20).

Social justice and equality

An important statement on the 20th Waigani Seminar was, that if PNG is to have sustainable development it must first have peace and social harmony (ANONYMOUS 1993, 18). Economic development should be directed towards achieving basic social justice objectives and equal opportunities to participate in, and benefit from it (cf. Agenda 21, 1.1; CPNG-P, 2nd+4thgoal). The other major principle is intergenerational equality (RDED, prin. 3, cf. above).

Strategies

The last aim mentioned above must be the base of all strategies for sustainable development as explained above.

For intragenerational equality in subsistence farming on a local scale, rural producers of food and forest resources, especially women and landless people must be given fair access to soil, water and forest resources (Agenda 21, 14.17, NSDS, 8). It is therefore necessary to assign clear titles, rights and responsibilities concerning land, persons or groups (cf. Agenda 21, 14.18; NSDS, 3.1). Efficient use of on-farm inputs and minimal use of external inputs is most appropriate to guarantee equal opportunities for all small-scale farmers with low cash incomes (ibid., 14.18; 32.5). Still, technological, financial, marketing, processing or sale possibilities, seed and plant material, as well as knowledge, training and education concerning sustainable agriculture have to be equally provided (Agenda 21, 14.18). Therefore a sufficient minimum of infrastructure like schools, markets, transport and information transfer is necessary.

As involvement of all social groups is an essential factor to guarantee equality Agenda 21 (23.1; 24.0; 25.2; 26.3; 32.5.) and likewise the NSDS (2; 3; 3E; 8.6-7) point at the special strengthening, better participation and representation of often underprivileged groups such as women, children, youth, indigenous people, and farmers.

Guarantee of a productive and healthy life and satisfaction of immaterial basic needs

Prin. 1 of the RDED points out that human beings are entitled to a healthy life in harmony with nature. Thus sustainable AF must conserve a healthy environment, clean drinking water and particularly ensure sufficient and healthy food, and also essential medicine if possible (cf. Agenda 21, 6.3).

Not clearly defined in Agenda 21 and RDED (prin. 1) is the goal of 'satisfaction of basic human needs' and 'productive life in harmony with nature'. It should be clear that, besides the material needs mentioned above, higher-level social and cultural necessities such as security, freedom, education, employment, and recreation are included (cf. BROWN, LEMMONS 1995, 14).

Others might also be religion, traditional culture, social contact, contentment with personal situation and identification of personal environment, all of which are necessary to improve well being and also human health.

Strategies

Most strategies concerning the goal to ensure human health have already been described under the ecological and economic aspects. Additionally it is noted in Agenda 21 (6.5) that, as appropriate, traditional knowledge and experiences should be integrated into the national health service. In this context, and according to the goal of self-sufficiency and 'PNG ways' (CPNG-P, 5th goal) the importance of traditional healing must be recognized and it should be investigated what traditional medical resources may be available and acceptable in the modern context to further promote them in AF (cf. JENKINS 1992, 391).

Strategies to satisfy immaterial needs and ensure a productive life are manifold and may include participation to safeguard an independent and self-guarded lifestyle, promotion of self-reliance, development that promotes or is in accordance with traditional knowledge, culture, customs and resource use (cf. RDED, prin. 22; Agenda 21, 14.18+22; NSDS, 7+8; CBD, Art.8j;10c). Many other aspects are already referred to above.

'PNG ways', a national strategy outlined in the fifth goal of CPNG-P and similarly expressed in the NSDS (4.A.19; 8) means that development must be achieved primarily through use and protection of PNG forms of social, political, and economic organisation and its other social, cultural, spiritual and physical resources, with emphasise on the moral and spiritual importance of conservation. This shows that PNG broadens the anthropocentric approach of Agenda 21 and other Rio Documents, which contain little evidence in that humans owe moral duties to the natural environment or its components and that these things may possess a value of their own independent from their usefulness to humans (cf. BROWN, LEMONS 1995, 14).

1.2.3 Integrated approach

As a consequence of the manifold aims for sustainable AF, an integrated approach is needed for this study. Such an approach implies attention to the different *processes*, *sectors*, and *scales* concerned with sustainable AF.

Processes refer to an understanding of land-uses, for example, from an ecological or socio-economic perspective, whereas a *sector* is a land-use type, such as agriculture and forestry. The integration of both sectors through combination of tree and food products in AF can contribute to the fulfilment of many basic needs in the life of the rural poor in developing countries by providing materials, food, fodder, firewood, natural exudates and medicine. Furthermore, it prevents degradative processes and erosion of the soil and provides many other economic, ecological, and also socio-cultural benefits. AF intensification can only be accomplished successfully by tapping a greater array of biological resources and blending traditional knowledge with scientific research. As trade-offs are inevitably involved between natural and

socio-cultural resources and any economic development of an area, approaches in AF development must be identified which can mitigate those losses.

In a sustainable approach further different *scales* have to be integrated. This means that local efforts in the case of AF development need to be better integrated with international and national Agenda 21 frameworks. Agenda 21 (14.17, 32.4) demands participation and a decentralized approach to decision-making on a local level. This is indeed a precondition for sustainable AF development, because of the complexity of farming systems in the tropics and the enormous diversity of cultural and natural conditions in PNG. Decentralization is one of the means to tap local knowledge and necessary for the implementation and success of AF development, which depend largely on the interest and involvement of the individual farm households. The actual managers are the farmers. They understand best why they were forced to damage the environment on which they depend, and they are the key to rebuilding (TIMBERLAKE 1985, 232 pp). In order to be able to link individual actions to global or national concerns and thus to achieve sustainable land use, the community as an intermediate scale level seems to be most appropriate.

To conclude, an integrated approach to the developing of sustainable AF requires that at least two essential concerns are addressed:

- sustainability of land use (as an international, national, regional and local necessity)
- fulfilment of the needs of the local population.

Several methods have been developed which address these concerns, with the following ones being considered during this study:

- ***land evaluation*** or **evaluation of nature potentials** with the dominant concern to assess land suitability for selected and specific land-use types, including nature conservation, esp. on a regional but also local level, and
- ***farming systems research*** (=FSR) with main focus on the farm household and the non-agricultural sector as a system to understand real world economic systems in which farmers operate, for developing and disseminating improved technologies and practices, and for implementation of appropriate policy and support systems to facilitate the technological objectives (cf. COLLINSON, NORMAN 1985, 17).

Often, in land evaluation and also in landscape planning approaches like the evaluation of nature potentials (cf. BIERHALS et al. 1986; KIEMSTEDT et al. 1985; ARUM 1990; FAO 1976), socio-economic processes are not considered in detail. The main concern becomes the land and not its users. In FSR, in contrast to the former, the primary objective is the improvement of the well-being of individual farming families by increasing the productivity of their farms, given both biophysical and socio-economic constraints to production. In FSR it is a principle to obtain participation by farmers in the research and development process and to integrate the farmer's knowledge, by working in close cooperation with them and representatives of the local community (cf. FRESCO 1986).

Consequences for this study:

Consequently, the integration among the ecological, socio-economic, and land-use management processes is best safeguarded through combining the strengths of the different methods. There was not only one single standardized method applied in this thesis but techniques of land evaluation and FSR in combination with each other, as long as they were practicable on the local level and in the particular situation. This also depended on available skills, knowledge and support. As it was not possible to replace an interdisciplinary working team, which would indeed be the best solution for an integrated approach, and because planning in developing countries as well as the restricted time and money budget afforded pragmatic and objectives-oriented planning methods, parts of these methods were selected and applied to special themes (cf. chap. 1.1.4):

- To define environmental problems and opportunities in the study area relevant nature potentials of the planning unit were roughly determined and evaluated. Because in this thesis the main emphasis is directed toward sustainable AF, the soil potential and the potential of biological resources for AF were of special interest (evaluation of land/ nature potentials).
- For the identification of the community's or farmers' needs and human resources the socio-economic and cultural context of the village was investigated (FSR).
- To evaluate the strengths and weaknesses of the present AFS and for tapping local knowledge compatible with conservation or sustainable use requirements, the prevailing and traditional AFS of Gurakor was analysed (FSR).
- Based on this evaluation, methods and practices to improve the system and instruments to develop and disseminate the improved technology were searched (FSR, landscape planning).
- In all stages on site, enhanced communication, participation and cooperation of smallholders was necessary (FSR) but the full evaluation, design and planning stage could not be done in cooperation with farmers, as it was done in Germany during the allotted time of this thesis.
- Raising awareness and motivation towards sustainable AF was introduced (FSR) but testing practices and technologies in the village, disseminate them or doing steps of implementation (an important part of FSR) could not be done within the scope of this study.

Later the Diagnosis and Design method was found in literature, which similarly combines different planning approaches and which is directed towards a systematic, open-ended diagnosis of land use problems and designs of AF solutions on variable scales, whereas involvement of farmers is seen to be particularly important on the lower scale-levels (cf. RAINTREE 1990, 41).

The present study mainly follows a socio-cultural and ecological approach rather than the quantitatively analytic agronomic approach. This helps to tap already existing knowledge by offering details on the past and present AFSs that have been empirically and informally developed and have much to offer in the search for sustainable AF.

Some exogenous circumstances like urban-rural relations, interdependence and globalization of trade, national price policy or external development assistance and development financing, which today effect farming systems and agricultural development in rural areas of PNG, were investigated and mentioned in some cases but are not a major object of this investigation.

2 DESCRIPTION AND EVALUATION OF LOCAL RESOURCES FOR AGROFORESTRY

In this chapter, natural resources, divided in physical and biological ones; and human resources, socio-cultural and economic aspects are described and evaluated as long as they are relevant for sustainable AF development in Gurakor.

2.1 Physical resources in Gurakor

Physical resources include land form, rock type, soil, climate and water systems. Some information is derived from the PNG Resource Information System (PNGRIS). It divides the land in basic spatial units of the system known as Resource Mapping Units (=RMU)[13] to describe natural resources, current land use and population distribution (cf. BELLAMY, McALPINE 1995, 2). Still it was designed for a national or provincial planning level carried out on a map base of 1:500.000 and is therefore not very detailed.

2.1.1 Description of land form, rock type and major soil groups

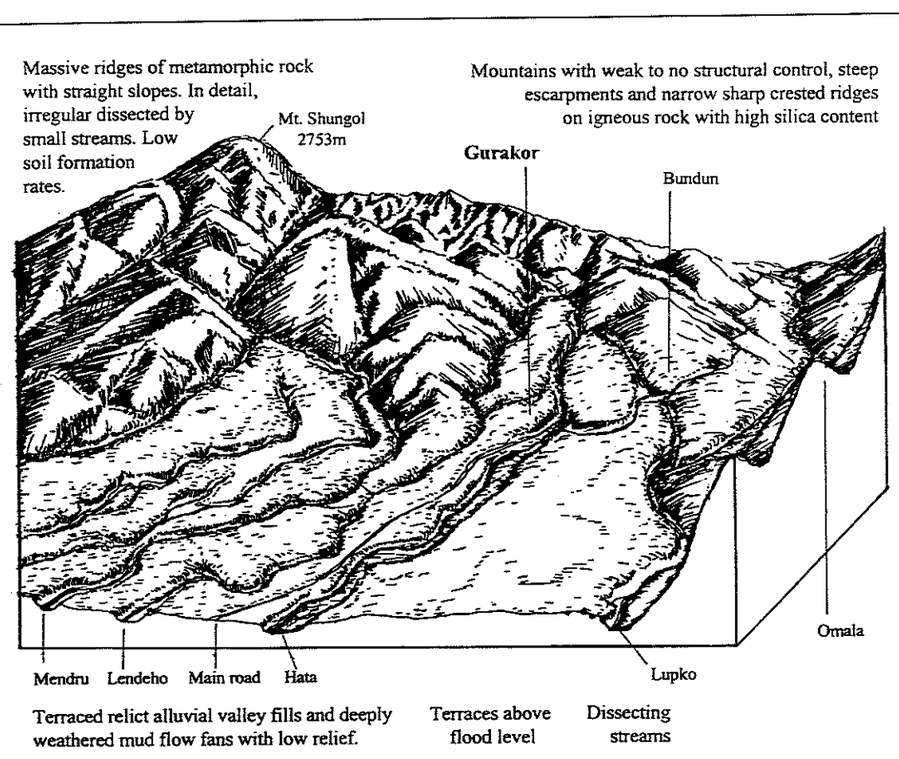


Fig. 4: Landform and geology in Gurakor

[13] An RMU is an area of land that has the same pattern of landform, geology, climate, hydrology and soils throughout its extent (BELLAMY, McALPINE 1995, 3).

The following description can best be understood when it is compared with fig.4.

Although there is no map of a detailed distribution pattern of soil types, there surely exists a complex series of different soil types according to geology and lively changing topography. The mountains and hills have weak to no structural control, steep escarpments with narrow sharp crested ridges and are separated by V-shaped valleys with steep river gradients. Besides the mountains south of the river Hata on coarse grained acid to intermediate igneous rocks with relatively high silica content, such as granites and granodiorites (PNGRIS, RMU 245), the larger part of the mountains and hills in Gurakor is on relatively fine grained low grade metamorphic rock, such as slates and phyllites north of Hata (PNGRIS, RMU 384). The latter consist of massive ridges with straight slopes in the overall profile but which in detail are irregular and dissected by a network of small streams and gullies that are followed by foliation planes. Because geologically the land is relatively young it is characterized by 'recent' developing soil groups with usually shallow weathering. Particularly on steep slopes (20-30%), very shallow to moderately deep weathered soils like Ustropepts and Ustorthents recently developed. Those steep slopes were and still are only in a few cases cleared from forest.

The terraced relict alluvial valley fills and associated colluvial deposits or mud flow fans, composed of sand, gravel, silt, mud, clay or angular rock fragments, are quite strongly weathered and moderately to strongly dissected by narrow streams (Hata, Lupko, Mendru and Junin). Thus the terraces with low relief (10-30m) and 0-8% gradients are above the present flood level of dissecting streams and no longer subject to active depositional processes. According to the PNGRIS (RMU 224, 245, 384) and spot checks in Gurakor on those terraces deeper soils such as Tropudalfs predominate additionally to the already mentioned Ustorthents and Ustropepts. Minor soil groups covering less than 20% of the land are neither listed in PNGRIS nor were they studied in Gurakor so that the following data should be considered indicative only.

According to the US-Soil Taxonomy and studies by BLEEKER (1983) in PNG the three major soil groups are generally described as follows:

Ustorthents (Entisols)

- Shallow to very shallow soil (0-50cm) or bare rock, typically found on recent erosional surfaces with slopes greater than 25% (11°) or induced by cultivation or other factors,
- usually undifferentiated without any diagnostic horizon with dominance of mineral soil materials like moderately stony/rocky normally black, dark greyish brown sandy loam to clay (BLEEKER 1983, 47pp),
- well drained and subject to seasonal moisture stress for less than 90 days,
- hard to allow a general characterization of nutrient content and base saturation as it is directly related to the materials from which they are derived (cf. table 2).

Ustropepts (Inceptisols)

- Moderately deep (<1m) soil, mainly found on food slopes and gently to moderately sloping hill slopes,
- with yellowish brown, brown or reddish brown, fine textured or gravely clay soil,
- moderately to well drained and subject to seasonal moisture stress: dry in some parts of the soil for at least 90 days in any year,
- slightly to moderately weathered or leached and little accumulation of translocated materials,
- rich in bases and fairly high amounts of exchangeable sodium in the subsoil (ibid., 95pp),
- erosion hazards on moderately sloping terrain limit arable cropping.

Tropudalfs (Alfisols)

- Deep (>1m) soil, often on flat or gently sloping terrain, comprising fine textured sedimentary rocks or their colluvio-alluvial derivatives,
- moderately weathered with an ochric (pale) epipedon and finer textured (argillic) subsoil, meadow (podsolic) soil lacking pronounced reddish colour, brown or red soil (chromic), or plastic heavy clay soil,
- well to imperfectly drained, good supply of water, but still moisture stress during short dry period,
- medium to high supply of bases, in general no major constraints related to acidity,
- with ferric properties and negative properties due to low activity of clay fraction and low total amount of plant nutrients, e.g. absence of high exchangeable sodium and very common calcium deficiency, or phosphorus fixation.

Fig. 5: Ustropept or degraded Tropudalf invaded by Imperatra grass, Gurakor, Gwa July 1997.

2.1.2 Natural production potential of the soil

The soil attributes mentioned above are used as criteria to distinguish 'great soil classes' according to the US Soil-taxonomy (USDA. 1975) but are often inadequate with their typical characteristics for matching crop requirements to land characteristics. Therefore PNGRIS has added information to describe the production potential of the different soil groups also in the mapping units of Gurakor.

Chemical and physical properties of the soil

The following description of soil attributes derived from PNGRIS (RMU 224, 245 and 384) and BELLAMY, McALPINE (1995, 101pp) are divided in physical and chemical properties (cf. table 2). Some properties of Ustorthents differ, as they are directly related to the materials from which they are derived. This is expressed in the column of Ustorthents (table 2) through the following abbreviations of the prevalent rock types in the planning unit:

lm = low grade metamorphic rock ig = igneous rock al = alluvial deposits

GREAT SOIL GROUPS (ORDER)	USTORTHENTS (ENTISOLS)	USTROPEPTS (INCEPTISOLS)	TROPUDALFS (ALFISOLS)
		PHYSICAL PROPERTIES	
Rock types	low grade metamorphic igneous rock or alluvial deposit	low grade metamorphic igneous rock or alluvial deposit	alluvial deposit
Stoniness/rockiness	Moderate (3-15%)	slight (1-3%)	not stony/rocky (<1%)
Effective soil depth	Shallow (25-50cm)	moderately deep (0,5-1m)	deep (>1m)
Topsoil texture (0-25cm)	Medium [a].	medium [a].	medium [a].
Subsoil texture (25-100cm)	lm+ig=medium [a], al=coarse [b].	medium [a].	medium [a].
Soil drainage	well-drained	well-drained	well-drained
AWC [c] (0-25cm)	lm=very low, ig+al= low	low (3-5cm)	low (3-5cm)
AWC [c] (0-50cm)	lm=very low, ig=moderate, al=low	moderate (5-10cm)	moderate (5-10cm)
AWC [c] (0-100cm)	lm= very low, ig= high, al= low	high (10-15cm)	high (10-15cm)
Soil erodibility [d]	moderate	moderate	moderate
		CHEMICAL PROPERTIES	
CEC [e]	moderate (10-25 meq%)	moderate	moderate
Base saturation [f] (topsoil)	lm+ig=high, al = moderate	high (>60%)	moderate (20-60%)
% total N (topsoil) [g]	low (<0,2%)	low (<0,2%)	moderate (0,2-0,5%)
Available P [h]	low (<10ppm)	low (<10ppm)	moderate (10-20ppm)
Exchangeable K [i]	moderate (0,2-0,6meq%)	moderate	moderate
Anion fixation [k]	no problem	no problem	no problem
Mineral reserve [l]	high	high	moderate
Soil reaction (H_2O= 1:1) [m]	weakly acid to neutral (5.5-6.5)	weakly acid to neutral	acid (4.5-5-5)
Salinity	none	none	none

Table 2: Chemical and physical properties of the soil

BOX 4: Some explanations concerning physical soil properties

[a] **Medium texture** is sandy loam, loam, silt loam, silt, silty clay loam, sandy clay loam, clay loam, organic mud.

[b] **Coarse texture** is sand, loamy sand or gravel.

[c] **Available water holding capacity** (=AWC) is the amount of water held in the soil between tensions corresponding to field capacity (=FC) and permanent wilting point (=PWP). Although the AWC gives reasonable approximation of the total amount of soil water available for crop growth, its significance to agriculture emerges to be secondary under high rainfall conditions in Gurakor. To distinguish between shallow to deep-rooting crops the AWC has been calculated for three different root zones.

[d] **Soil erodibility** was measured by taking soil texture of surface horizon and organic matter content into account and will be discussed more detailed below.

BOX 5: Some explanations concerning chemical soil properties

[e] **Cation exchange capacity** (=CEC) is a measure of the soil's ability to retain cations against downward leaching and thus to affect the nutrient retention capacity of a soil. It was only assessed for the topsoil layer (0-25cm) because vegetation obtains most of its nutrients from the surface horizon(s). All of the three soil groups have moderate CEC (10-25 meq%) which will further decrease with the loss of organic matter that significantly contributes to CEC in tropical soil (cf. MUELLER-S et al. 1986, 106).

[f] **Base saturation** (=BS) is an expression of the quantity of cations available for plant growth in relation to the CEC.

[g] Most of the **Nitrogen** (=N) occurs in the surface horizons in combination with organic matter, N is generally the most poorly correlated with plant growth and subject to rapid changes following forest clearing and cropping.

[h] Data on **available phosphorus** (=P) in PNG soils are very limited. Therefore, general conclusions on soil P content are very difficult.

[i] **Potassium** (=K) distribution in the soil, in contrast to N and P, follows a pattern which is related to the presence or absence of K-bearing mineral such as micas and K-feldspars and the degree of weathering in the soil.

[k] **Anion fixation** attempts to delineate soil with high P fixation capacities or low rate of N mineralization, so that determinations of P and N content alone are insufficient for the assessment of the N or P status. That there are 'no problems' in the three soil groups means according to BELLAMY, McALPINE (1995, 112) that P-retention is less than 60% and the Carbon/Nitrogen ratio less than 14. As a consequence the P-deficiency of the soil may be relatively easy corrected by good management of organic matter as an important P-source or small fertilizer applications.

[l] The **mineral reserve** influences the soil's long term productivity, because it reflects the presence or absence of potential plant nutrients and it also influences the available water content. It is of particular importance to subsistence farmers because they generally apply very few, if any, fertilizers.

[m] A acid **soil reaction** or pH value of less than 5 like in Tropudalfs indicates that a very low supply of bases (such as N,K and Ca) necessitates good plant nutrition management. Moreover low pH rates can lead to aluminium toxicity problems and P-fixation which can even increase with physiological acid fertilizers like sulfate of ammonium ($=NH_4SO_4$), (cf. SCHACHT. et al. 1992, 121pp). Through Al-toxicity a decrease in root growth and water stress is very likely even in soil with high water capacity.

Further observations on chemical properties

The quality of soil was also judged by observing the covering vegetation or special pointer plants. The widespread invasion of cane grasses (*Phragmites/Saccharum*), *Imperata* grass (Kunai) and the woody species Well daka (*Piper aduncum*) indicated land degradation (cf. TURVEY 1994, 19), whereas the well-doing of care-intensive food crops such as yam helped to identify fertile and deep soil. As villagers stated, the latter is hardly planted in Gurakor anymore, because there are only few very deep and fertile soils available[14]. Growth reduction of taro is widely recognized on land under more intensive cultivation with only 4 year-fallow, which makes the largest part of cultivated land in Gurakor, and it is more and more replaced by the less

[14] Besides, the need for high labour input has contributed to the reduction of this highly nutritive and storable crop.

demanding sweet potato.

On some plots leaf anomalies especially of taro showed P-deficiency through gradual paling and red pigmentation of the petioles and necrotic lesions (cf. ASHER et al. 1995, 84pp), and N-deficiencies, that result in a general chlorosis and senescence of the oldest leaves (ibid.). Indications of K, zinc (=Zn), iron (=Fe), or magnesium (=Mg) deficiencies were not visible and signs of toxicity problems of boron (=B), manganese (=Mn) or Zn were also not found.

It has been suggested by several individuals, e.g. JAINGO, JOHN and JALING (1997) that the productivity of soil has been deteriorating during the last decade under the present forms of land-use. Over the years there has been an increasing intensity of various soil degradation processes. Three soil samples showed the very limited content of organic matter in the top soil (4% on Lipago), which indicates the unsustainability of present soil management practices.

2.1.3 Assessment for sustainable use of soil

This section presents an assessment of the probable physical or chemical constraints to sustainable land use and it is expressed in terms of potentials to absorb uses like agricultural intensification and land clearing. The resource attributes considered are the general and inherent soil fertility of the three different soil groups, the risk of soil degradation, leaching, and erosion offset against soil formation rates. Rainfall erosivity and angular contingent soil erosion susceptibility are assessed to allow determination of the potentially multiplicative effects of soil erodibility, rainfall erosivity and slope. Finally the influence of cropping methods on erosion, the risk of mass movement and floods are discussed. Either the evaluation done by PNGRIS was taken or it was guided along the land evaluation methods of ARUM (1990) and BASTIAN, SCHREIBER (1994). As explained in chap. 1.1.4 simplified evaluation methods had to be applied and assessments were merely done by verbal reasoning rather than calculative models.

General and inherent chemical fertility

General chemical fertility, which is based on five attributes namely CEC, BS, total N, P. and K is according to PNGRIS low in most of Gurakor's soils with exception of Tropudalfs on alluvial deposits with a moderate one. The inherent fertility, which refers to the ability to restore itself after the protective topsoil has been eroded, is assessed by combining the ratings of mineral reserve and the effective soil depth (ibid., 128). This will influence the rooting ability of plants and hence the potential to take up soil nutrients. The mineral reserves are high in most of the soils because the land in Gurakor is relatively young and slightly weathered, but shallow soil is fairly common on steeply sloping terrain, particularly on hard rocks. Inherent fertility is therefore low in Ustorthents, moderate in Ustropepts and high in Tropudalfs (PNGRIS, RMU 224).

Vulnerability to soil degradation

It is important to realise that the productivity of a particular soil at any point of time is the result of ongoing degradative processes and applied management practices. Due to moderate CEC combined with good drainage and high rainfall in Gurakor even high amounts of inorganic

fertilizer cannot contribute to sustainable conservation or increase of the production potential of the soil owing to high wash outs. Thus the use of high doses of inorganic fertilizers may become a major contributor to soil degradation. Chemical degradation of the soil is mediated through processes that induce leaching of bases, development of acidity, deficiencies of certain nutrient elements or accumulation of metallic ions. This is very likely in Tropudalfs through excessive removal of bases from the surface soil, leading to disorders in crop plants. Besides toxicity of Fe, the crops may experience deficiency of P and Zn. Often toxic concentration of Mn may also be encountered in such soils (SINGH 1994). All these factors lead to a decline in soil productivity.

Many authors stress the key role of organic matter in tropical conditions for the maintenance of CEC, buffer functions and nutrient source and thus for soil fertility. The major fraction of nutrients is locked up in the biomass and it is the remaining minor fraction that contributes to the soil pool. Organic matter reduces soil erodibility, helps to maintain an active population of soil organisms and thus promotes and stabilizes a favourable physical conditions like soil structure (cf. MUELLER-S et al. 1986, 116). As in tropical climatic conditions like in Gurakor the rate of organic matter decomposition is very fast (cf. chap. 2.1.5), all organic manure or other matter added to the soil are mineralized easily and it is difficult to raise the level of organic matter content significantly. A rapid decline in organic matter content of soil after it is taken into production leads to a gradual decrease in soil bulk density and as a result, soil forms a surface crust, which, in turn, inhibits aeration and reduces infiltration (cf. GREEN. 1994, 9).

To sum up sensibility to soil degradation in Gurakor's soil under tropical conditions is very high.

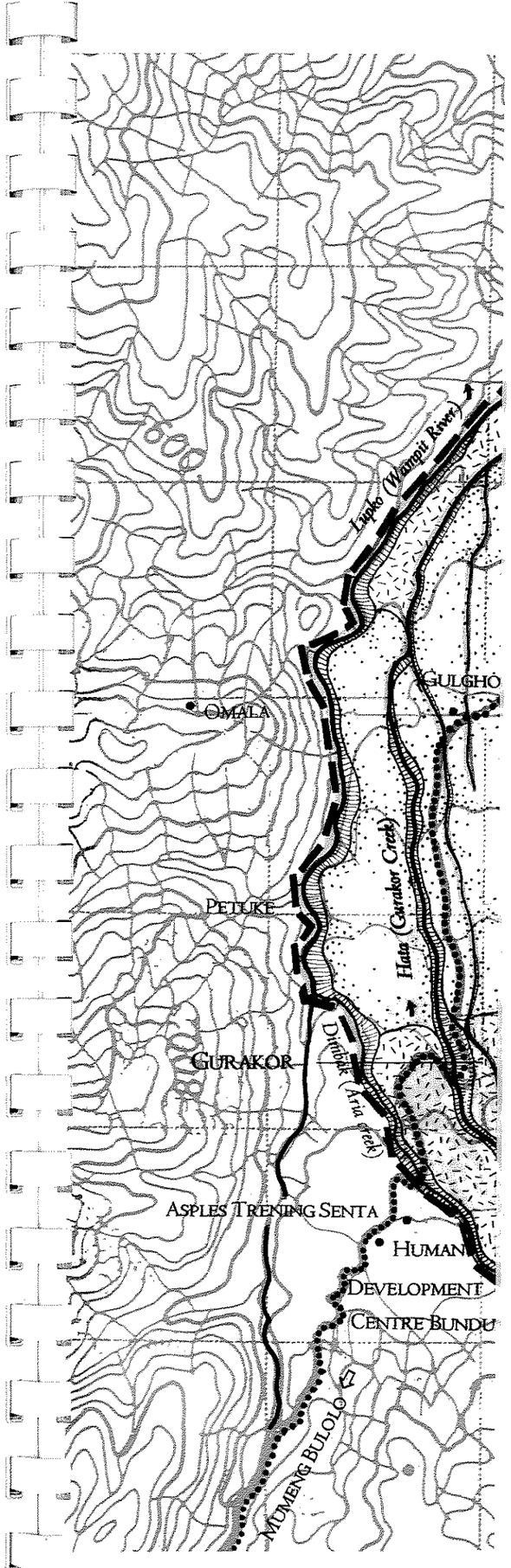
Sensitivity for soil erosion

Soil erosion is by far the most widespread among different soil degradation problems. It has serious adverse effects both on-site in terms of reducing productivity and off-site effects in terms of pollution. Soil erosion caused by rainfall is a function of rainfall erosivity, soil erodibility, slope (and slope length) and cropping practice (cf. BASTIAN, SCHREIBER 1994, 199). Those different factors are reviewed below except of the last point which is discussed in chap.3.

Rainfall erosivity[15]

Estimated mean annual rainfall erosivity in Gurakor is according to PNGRIS (RMU 224) from May to October very low (<10,000 Joules per m^2) and from November to April low (10,001-20.000 Joules per m^2). Yet, this calculation is based on a 2000 mm annual rainfall which is controversial to measurements of McALPINE et al. (1975, 25. 59) who recorded 2800 mm mean annual rainfall in Gurakor and monthly rainfalls up to 606 mm in particularly wet years with 3420 mm. These measurements can be supported by figures based on experience so that rainfall erosivity should be adjusted upwards to at least 'moderate' or even 'high' in the rainy season.

[15] Rainfall erosivity is an estimate of the relative energy of falling rain to stimulate erosion, and has been mapped and calculated for the PNGRIS by BELLAMY (1995a).



DEVELOPMENT CONCEPT OF AN APPROPRIATE AND SUSTAINABLE AGROFORESTRY SYSTEM FOR SUBSISTENCE FARMERS IN GURAKOR
Map n° 2

CLASSIFICATION OF LAND CAPABILITIY FOR AGROFORESTRY

Legend

Slope	Land Capability Class
0 - 8 %	**A** land with good flexibilitiy for growth of annual and perennual crops
>8 - 16 %	**B** land with moderate flexibility, marginal to some crops but without mechanization still optimal
>16 - 30 %	**C** land with low flexibility, requires special erosion control, preferably perennial crops
> 30 %	**D** land unsuitable for cultivation, perennial crops can be grown with special erosion control

rivers and creeks

main road (sealed)

demarcation line of the study area

Scale 1:25 000

N
S

Diplomarbeit
Institut für Landesplanung und Raumforschung
Hannover 1998
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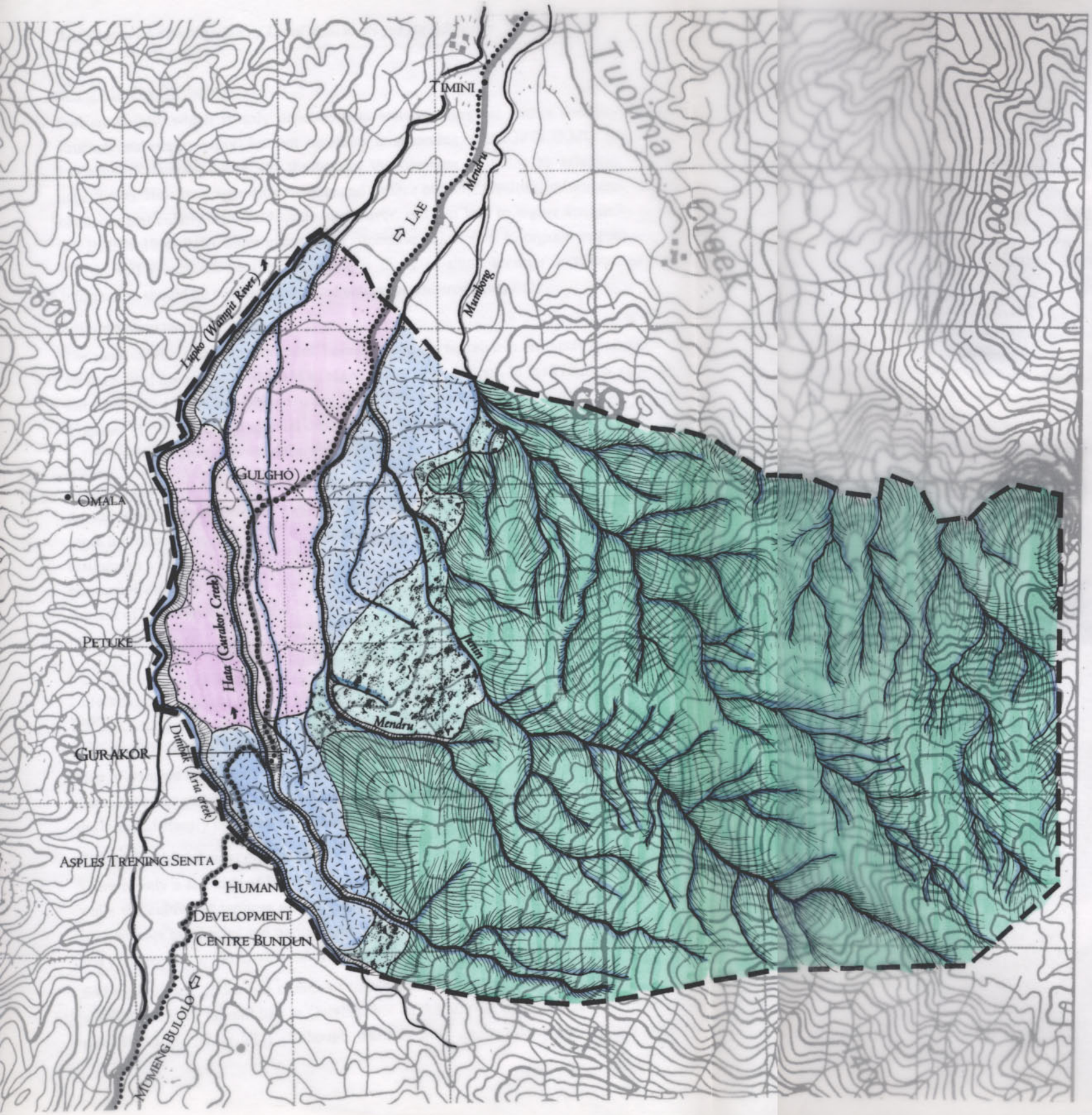
Ursula Nothhelfer



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Soil erodibility (K factor)

Soil erodibility, which is only dependent on soil type (organic matter content, soil texture, structure and permeability) but not on slope, is according to PNGRIS (RMU 224, 245, 384) moderate (K-factor= 0,20-0,40) throughout the planning unit due to relatively stable soil aggregation. However, aggregate stability and surface capping, resulting in increased run-off, are common, particularly with inadequate crop cover, and can lead to higher sensitivity to erosion (cf. BEETS 1990, 219). Since many of the attributive values (e.g. % organic matter) vary within a great soil group, the resulting K-factor is likely to show a range in values, so that this information should be used as general indication for soil erodibility only.

Soil formation rates

The same is with soil formation rates, because there are no reliable estimates available on those for the humid tropics (cf. BELLAMY, McALPINE 1995, 129pp). In the PNGRIS, estimated soil formation rates, that are derived using rock type, temperature and rainfall, are, in Gurakor, moderate (1.5mm/year) on alluvial deposits, and low on low grade metamorphic rocks and acid to intermediate igneous rocks of the mountain ranges

Angular contingent soil erosion susceptibility

As soil erodibility of the three different major soil types and rainfall erosivity appear to be the same throughout the planning unit, the factor slope seems to be the most appropriate factor to distinguish vulnerability towards rainfall erosion within the planning unit. It is distinguished between 4 different gradients that indicate the angular contingent soil erosion susceptibility or the risk of soil erosion in general:

SLOPE GRADIENT	DESCRIPTION	RISK OF SOIL EROSION
< 8% (-4,6°)	Flat to slightly undulating	low
>8-16% (-9°)	Undulating	medium
>16-30% (-16,7°)	Rolling hills	high
>30%	Hilly to steeply dissected	very high

Table 3: Slope and risk for erosion (simplified acc. to BASTIAN, SCHREIBER 1994, 201; FAO 1979a, 39p)

Map n°2 shows the different slope gradients. Land with low to medium risk to soil erosion and therefore better suitability for cultivation is restricted to the alluvium and mudflow fans whereas the hills and steeply dissected mountains bring about high to very high risk towards soil erosion.

Risk of floods and mass movement

There is only a low risk of inundation in a small area along the main streams, Hata and Lupko while the cultivated terraces are above the present flood level of dissecting streams. Flooding only appears to be brief and periodic for 3 to 4 days or less as a result of a brief river overflow and ponding due to intensive rainfall events (cf. BELLAMY, McALPINE 1995, 93).

Soil slips, slides, glides and mudflows together categorized as mass movement are common in areas of intensive rainfall like in Gurakor, but on the alluvial mud flow fans there is usually no risk (PNGRIS, RMU 224). Although there is little doubt that landslides are triggered by

Impacts of seasonality on smallholder economy

The uneven distribution of agricultural activities and events has a pronounced effect on smallholder economy. Climatic seasonality leads to the uneven distribution of labour over the year and season-tied production leads to both shortages and surpluses of products. As a consequence changing cash incomes are causing seasonal fluctuations in food and fodder availability and nutritive status. Especially at the end of the dry season, when the highest labour input is required to prepare and plant new garden plots, food availability and food intake is at its lowest thus limiting the work-capacity.

Irregular perturbations of climate, climate change and their impacts on agriculture

PNG, like Indonesia, Australia, and the western Pacific, experiences irregular perturbations in temperature, humidity and rainfall, which are associated with the El Niño Southern Oscillation (=ENSO) phenomenon. Although the relationship between ENSO events and droughts in New Guinea is not a simple one, they are associated with periods of very low rainfall and frost in the highlands[16]. These events disrupt food production and are still associated with famine and an increase of mortality as the last event in 1997 showed. Coupled with cyclones and uncontrolled fire, caused by traditional slash and burn, enormous and sustainable damage has been caused.

Climate variability and climate extremes may increase as a result of global warming (FAO 1997). As mentioned in the introductory part, agriculture is not only a victim of global warming but also a contributory factor (ibid.). The role of tropical ecosystems in mediating change in the global environment remains controversial, as do the possible effects of global climate change on the human societies and natural resources of the tropical regions. However, no matter how climatic variability is caused, it already has and will have extreme impacts on agricultural production, slashing crop yields and forcing farmers to adopt new agricultural practices in response to altered conditions. In the tropics, higher temperatures will generally have negative influence on the crop environment and the 'wetter than now' and 'drier than now' would have a mixed result. On the optimistic side, it might be argued that higher levels of CO_2 have a fertilizing effect for many crops, encouraging growth rates and improving water use efficiency, but experts point out that the many question marks remaining over this scenario overweight the possible benefits (cf. ibid.).

2.1.6 Water systems and water supply

The prominent ranges of mountains in the east and west of the main valley are dissected by many small streams and some waterfalls. The valley bottom with its cultivated lands is drained by a system of waterways forming terraces in between (cf. map n°3). There are no data available

[16] BERGMANN noted that there has seems to be a change in seasons. Dry seasons appeared to became more dominant leading to an extreme long lasting dry period (El Niño) this year. Years in which it is known that widespread droughts and frosts at lower than normal levels have occurred in PNG are 1941, 1972, 1984 (ALLEN 1992, 45) and particularly severe in 1997.

about the ground-water system. Flooding and inundation is restricted to small areas of river beds in the Wampit valley, but is usually brief and periodic. There are neither village wells nor is irrigation necessary as under normal conditions there is a constant rainfed water supply. Clean drinking water for daily use in the main centre of settlement is mainly supplied by the large Gurakor Creek, Hata (cf.fig.6).

Fig. 6: Gurakor creek, despite severe droughts in 1997 still supplying sufficient and clean drinking water.

Its water catchment area is to the most extent unsettled, uncultivated and covered by rainforest. As most other dispersed settlements of Gurakor have their own water supplies with smaller creeks, there is until today no channelled water supply or sanitation within the settlements. Only in one exception, a simplified water supply with artificial ditches and joined bamboo and iron pipes has been installed to provide a small settlement between Gurakor and Bundun clean water, but usually these people wash themselves, their laundry and dishes in the large creek Hata like most other villagers. According to the villagers and own trials, every small and larger creek upstream the settlements is usable as drinking water because no chemical inputs other polluting factors are applied in the traditional land use system. However, with growing population, carelessness, inexperience and the growing use of external consumer goods (esp. batteries) may lead to serious pollution of downstream and ground water.

2.1.7 Vulnerability of water systems

Ground water vulnerability

The risk of leaching was already indirectly discussed above under 'soil degradation' as it highly depends on the characteristics of the soil. Due to good drainage in most of the soils, moderate CEC and high rainfalls, wash-out of pollutants such as batteries, fertilizers and other agrochemicals is very likely. Ground water vulnerability is thus very high, but also depends on water tables location, behaviour of particular contaminants and their pathways, human activity and many other factors which cannot be further discussed in this thesis.

Risk of surface water pollution and negative influences on water regimes

Silting is very likely where irrigation schemes are established and when gardens are established in close vicinity of river systems, flooding can cause severe erosion and water pollution. Such siltation of streams can reduce their capacity and increase their width. Another serious risk on surface waters is the extension of shifting cultivation into the mountainous water catchment area,

as it may lead to massive slope wash, erosion and high evapotranspiration rates after forest clearing. With increased runoff, there will be very little opportunity for rainwater to infiltrate, particularly when soil is already eroded. As a consequence there will be less moisture in the profile so that crops may suffer under moisture stress or drought at micro level. At the macro level such reduction in infiltration reduces the period of base flow thereby reducing the ground water recharge and even causing water table levels to drop (RAMA, RAO 1994, 131). As a result of severe water erosion and gullying, the volume of runoff and peak discharge for any given rainfall increases greatly from watersheds.

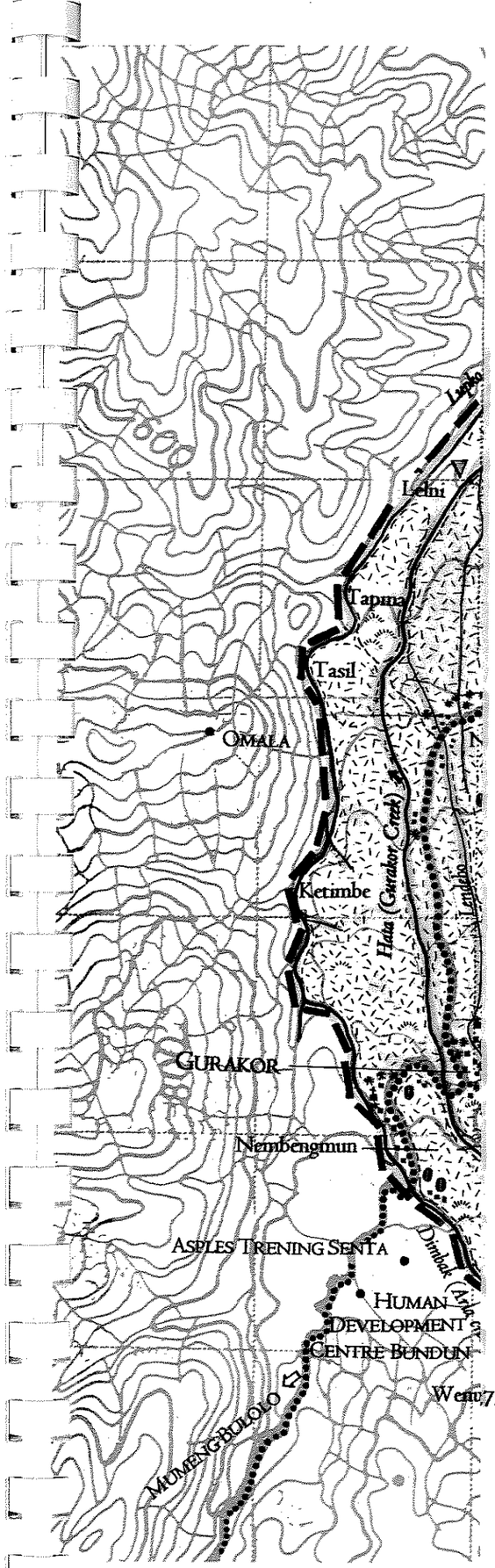
2.2 Biological resources and their potentials

In the land-use strategy of Gurakor's villagers almost all types of cultivated or wild lands are viewed as integral components of a larger AFS. This view has to be taken into consideration during this investigation of potentials of species and biotope in this chapter, as well as their vulnerability to land uses. Types of agricultural and wild lands found within the matrix of agroforestry systems include: native or secondary forest stands, sacred groves, few coffee plantations, small orchards, alternating cultivated plots with mixed tree- and ground-crops; some home gardens, vegetation along creeks and patches of grassland. Those different biotopes are described first and then some of their potentials are evaluated. Later, additional information is given about some species and their values for AF and subsistence. The endangering of biodiversity, biological resources, and their components through subsistence activities is discussed below in chap. 3.

According to the aims set up in the introductory part the evaluation of biological resources follows the line of the three different components of value people gain from them:

- The **direct economic** value of biological resources for the population, e.g. derived from their actual or potential usability for food, timber, construction materials, medical purposes, or renewable energy supply.
- The **ecological** or indirect economic value, which refers to benefits provided by various environmental services, including regulating the biological equilibrium of systems like climate and water purification, maintenance of soil fertility and absorption of waste products, etc.
- The **socio-cultural** value such as aesthetic, recreational and cultural value which may be particularly appreciated by people from developed countries or cities and is manifested when people engage in ecological tourism. It includes the ethical value that comes from the belief, common to many cultures, that life has intrinsic significance which means that its value is derived simply from the fact that it exists.

The overall significance for natural areas, based on these three categories is potentially great, but is rarely taken into account by traditional economists, who typically base their estimates only on direct economic value. Still the direct and indirect values of biological resources are too complex to be comprehensively evaluated in this study and their values are neither fully known nor can scientists predict which will become valuable in the future. Thus only some important uses and services that are already understood and those with special importance for AF and subsistence



DEVELOPMENT CONCEPT OF AN APPROPRIATE AND SUSTAINABLE AGROFORESTRY SYSTEM FOR SUBSISTENCE FARMERS IN GURAKOR
Map n° 3

CURRENT LAND USE

Legend

- primary / old grown secondary forest
- since 1975 used, with quite long fallow (7- 12 years)
- old gardens, with very shortened fallow (3 - 4 years)
- grassland
- taboo (not used for gardening)
- permanent grove
- coffee garden
- settlements of families
- church
- cemetry
- rivers and creeks
- main road (sealed)
- demarcation line of the study area
- rough bounds of major fields with field names

Scale 1:25 000

N
S

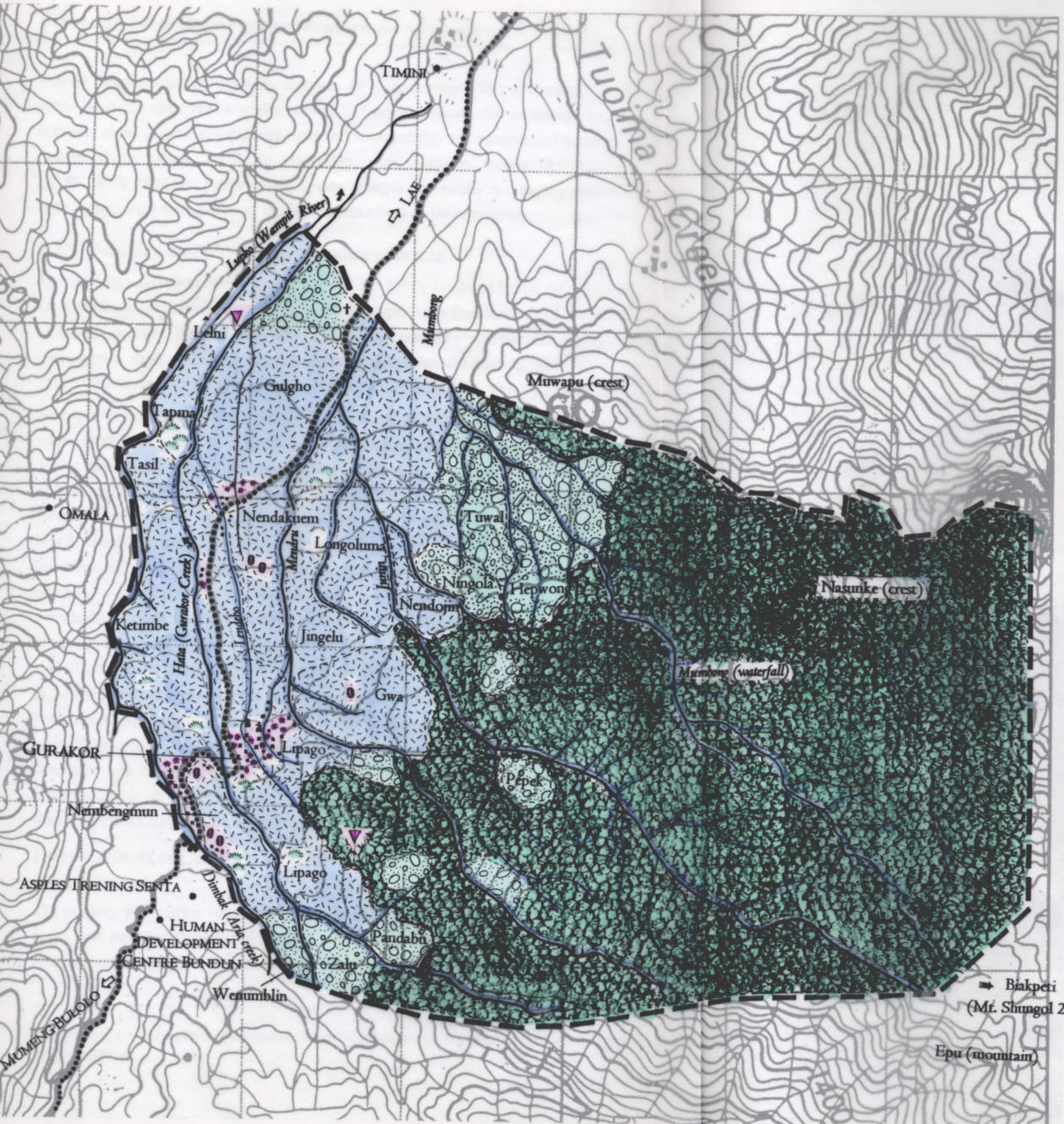
Diplomarbeit
Institut für Landesplanung und Raumforschung
Hannover 1998
Prof. Dr. Dieter Fürst und Dipl. Ing. Evelyn Gustedt

Ursula Nothhelfer

Development Concept of an Appropriate and Sustainable Agroforestry System for Subsistence Farmers in Gurakor

Map n° 3

Current Land Use



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will be described in the following sections. As a consequence, this evaluation can only provide some hints for their real complex values and are significant for awareness among the three different clans which have the only right and responsibility to conserve and sustainably use or to destroy these values. To make evaluation more operable, factors like **hemeroby** scale[17] (KOWARIK 1988) or **naturalness**, **rarity, complexity** and/or the **ability** of biotopes and/or their components **to regenerate** are used as indicators as far as possible.

2.2.1 Primary and old-grown secondary forests

The original vegetation of the Wampit Valley can hardly be found below 600 m above sea level. Only on the tops of the mountains and on steep slopes have forests survived the human activities of the last decades. It is not clear which pieces of forest are virgin because previous generations moved from strategic hill ridges to convenient riversides and back to other ridges again (talks with TOBIAS and JOHN 1997) leaving behind their garden plots which turned back to forest.

Few studies on tropical rainforests have been made in PNG both from an ecological and taxonomic standpoint and none at all in Gurakor. According to PAIJMANS (1976) and observations during this study, part of the remaining rain forest below 1000 m is **medium crowned low altitude forest on uplands**. The canopy of those evergreen, floristically very mixed and rich hill forests is lower than 30 m with some emergents rarely exceeding 40 m. This is mainly owing to less favourable conditions of steep slopes and shallow unstable soil than on alluvium. The shrub layer mainly consists of slender saplings, rattan, tree and shrub palms, tree ferns, scrambling bamboo, woody lianas, fleshy climbers and climbing ferns. Epiphytes abundantly grow on the trees and the forest floor is covered by a very patchy herb layer, due to the permanent shade. At lower altitudes, and adjacent to plain or fan, the forest has larger crowns, whereas at the higher end of its altitude range it forms a series of transition types gradually changing to the **small crowned lower montane forest** with a canopy 20-30 m in height. The canopy height decreases with increasing altitude and tree ferns become more common in the shrub and lower tree layers as well as epiphytes due to higher humidity with cloud cover. It would lead too far to list dominant tree or other species as there would already be dozens. The plants live in close relationships to an incredible variety of animal species, like insects, spiders, reptiles (snakes, lizards, geckos), frogs, birds, mammals, rodents, marsupials, bats, etc.

Value of primary and old grown secondary forests

Some indications

The primary and mature secondary forests in Gurakor are of very high value due to their enormous and obvious diversity in species, a high degree of naturalness (ahemeroby) and high complexity. Quantitative data on tropical rainforest characteristics such as the density, distribu-

[17] Hemeroby is the degree of human influence on ecosystems, taking into account human influences that confront a system to revert to its climax.

tion and natural richness diversity, rarity, fragility or other criteria for nature conservation are scarce in PNG. A study by PAIJMANS (1976, 70pp), however, showed that PNG's hill forests under 1000 m have up to 147 different tree species per ha, counted on a 0,8 ha plot with 691 individual trees. Thus their species richness is comparable with that of Borneo and Malaya which are the most diversified forests in the world. The study further showed that hill forest which makes up the largest part in Gurakor has a higher diversity in tree species than forests on flat river terraces and gentle foot slopes. These studies reinforce the impression that forests in Gurakor have an extremely high biodiversity with the exception of random parts and forests at high altitudes in the lower montane zone that show a slight reduction of species diversity. As there has not been any commercial exploitation until now (except for a trial without success to explore gold), the extending alternating cultivation and the effects of historic clearing and deforestation are besides some landslides and other catastrophic events probably the main cause for the reduction of biodiversity in some parts.

Fig. 7: A birdwing butterfly carefully held by a women from Gurakor, May 1997.

Gurakor's forests are home to many rare species and among these many such as orchids and some of the 66 endemic pandanus species besides many other typical rainforest species are endemic to the island of New Guinea. New Guinea is the only part of the world except for Australia that has representatives of all three types of mammals: The primitive egg layers (e.g. anteaters), the marsupials (such as possums, cuscuses, bandicoots, marsupial mice, tree kangaroos and wallabies), and the placental mammals, many representatives of which were seen or recorded by villagers of Gurakor. Of the 70 species of bats in PNG with 35 endemic ones many are common (and protected) in Gurakor. Many birds[18] like birds of paradise[19], at least 4 species of pigeons, the black palm cockatoo, many parrots, brush turkey and cassowary (interview with JOHN 1997), have survived in Gurakor's forests as rare species because they have been extensively shot or disappeared with the forests in many parts of PNG. Under the immense variety of insects the butterflies of PNG are maybe best known besides large praying mantises, stick insects and a

[18] There are 650 bird species in PNG, with 500 restricted to the forests

[19] Of the 43 species found world-wide 33 are endemic to PNG. They are all protected both by PNG law and by the Convention on International Trade in Endangered Species (=CITES), besides only 19 other 'National' (protected and government 'owned') animals (7 birdwing butterflies, 3 herons, 3 pigeons, 2 birds of prey, long-beaked echidna, dugong, Boelen's python and Salvadori's teal). It is with exceptions (permits) illegal to take, kill, disturb, possess, buy, sell or export them, but citizens can still kill these animals for traditional purposes and with traditional methods.

great variety of other locusts with mimicry. Many of them can be seen in Gurakor's forests like the butterfly in fig. 7, which is a member of the birdwings, the largest butterflies in the world, endemic to North Australia, Indonesia, from New Guinea. Out of the many rare of special species in Gurakor just a few were mentioned to indicate the great value of the rainforests.

Economic value

Besides the products that can be sold on foreign markets (logs, sawn timber, veneer and plywood, wood chips), here the main interest lies in the benefits for local people who get everything they need from these forests: food, shelter, tools, medicine, traditional bark-clothing, string for string bags and other uses, etc. These very important facts never show up in economic statistics, which usually just measure the direct use value that can be derived from various production strategies like logging and then converting the forest to cattle pasture, or timber plantation. Studies of forest resource profitability, however, are rare, although there is a very high potential of non-timber resources due to the enormous biodiversity and animal resources which for instance provide meat and highly valuable fur or feathers. About fungal mycelia called mycorrhiza, that are essential for the absorption of nutrients for many trees and crops and therefore of very high significance in AF studies also remain scarce in PNG. The direct economic value of rainforests not only for timber operations is thus very high, as will be shown below when benefits of special wild species will be explained.

Ecological value

Forests in Gurakor largely contribute to the regulation of hydrologic regimes. The water catchment areas of Gurakor rivers and creeks that are located in the mountains, are still covered by forests that ensure constant water purification of surface waters. This is particularly important in Gurakor where only surface water is used as drinking water. Even in times of massive droughts, as experienced during El Niño events in 1997, forests helped to ensure reliable supplies of surface and groundwater whereas in many grassland areas (e.g. in Markham and Ramu valley) large water systems rapidly dried out. Forests in Gurakor effectively control run-off and flooding, they prevent erosion or disasters through landslides on steep slopes and their severe influence on agriculture. The forests attribute to the stabilisation of climate on a global and regional scale, e.g. as CO_2 -sinks (cf. chap. 1.2.2), they mitigate droughts which may effect agriculture and improve the quality of the air. To reach a conclusion the forests in Gurakor esp. on steeplands and in water catchment areas are very precious and essential for now and for the future due to their many beneficial service functions.

Socio-cultural value

Is difficult to evaluate the socio-cultural value of forests from the villagers' points of view. Before christianization and to a certain extent today, many have revered, avoided or tabooed 'masalai'-inhabited areas. As villagers recorded there are, with some exceptions, only 'good' places today, few of which with an exceptional high value and with taboos on slashing and burning for cultivation, on other uses or even entry (cf. map n°3). As the forests provide many

materials and objects which have been used and are in some cases still used for healing, sorcery and other traditions, they have great immaterial or spiritual value for the population. From a western point of view the tropical rainforests of Gurakor with their immense variety of animals and plants, waterfalls and creeks, sounds and smells are extremely valuable for their aesthetic recreational and ethic entity. It may also be derived from the more abstract pleasure of knowing that natural areas, plants and wild animals exist even if a person never travels to see them.

To sum up, the value of Gurakor's forest is already immense for the local population due to its many functions and services, but also on the regional up to the global level, whereby many benefits (e.g. for science, breeding, medicine, etc.) still remain unknown.

Sensitivity and regeneration potential of the forests

Although plants and animals and products derived from forests are often considered as renewable resources, they may exist in limited quantities because of the common scarcity of a species in such diversified systems. The ability to maintain them depends greatly on how they are managed. Exploitation, e.g. over-hunting and large scale logging, can leave certain species without commercial value or can even drive them to extinction. The former primary forest will only recover on soil that is not too impoverished, if there is an intact primary forest nearby and if the succession is able to continue without any more outside disturbances (cf. chap. 2.2.2). Still it would take 100 and 1000 years until the forest is totally restored (cf. PAIJMANS 1976, 80p; KUBE 1990, 10). As studies in the Golgol valley, PNG, showed, a single cycle of selective logging does not appear to diminish plant diversity but subsequent clearance for agriculture and large-scale logging with heavy machinery is a serious problem (ibid). Today most of the remaining primary forests in Gurakor do not stand on fertile soil and a vast amount of its nutrients is stored in the biomass above ground. Therefore even a single cycle on those marginal lands, with a high risk for erosion and export of high amounts of biomass can make regeneration almost impossible and give way to better adopted non-indigenous and weedy species on impoverished soil (cf. chap. 3.2.1). Usually, once virgin forest is cleared today, it will remain under cultivation. As a consequence, the diversity of wild plants and animals will decrease significantly constituting a high loss of economic, scientific, ecological and socio-cultural values, which today have not yet been fully understood and evaluated. From all this follows that the very complex rainforest ecosystem in Gurakor on marginal lands is highly sensitive to disturbances and overuse and after those it is very unlikely that it will regenerate to the original diversified system.

2.2.2 Crop land and secondary regrowth

Near the settlements and the road, the valley bottom has almost completely been cleared from its virgin forest and is now devoted to cultivation (cf. fig.5; map n°3). These relatively flat plains on alluvial soil are used for the production of staple food, vegetables and fruits and contain a permanently shifting patchwork of garden plots, interspersed with secondary growth and trees that have been planted or just left standing for their edible fruits or other resources (cf. fig. 6).

Fig. 8: Aerial photograph over Gurakor's cultivated food plains with Wampit River on the right and Gurakor creek in the middle, 1997.

Fig. 9: Aerial photograph of the patchwork of cultivated and fallow land close to the Muwapu Crest, Gurakor, 1997.

As this is a highly fluctuating and changing patchwork, it would be pointless to describe and evaluate cropped and fallow land separately. Today, the garden rotation cycle is very short (down to 4 years), and only young regrowth stages are present on most of these sites. Even at great distances from the village, primary forest is cleared for new garden plots. In these gardens, fallow periods are still longer, various stages of secondary forest develop, and in some places the climactic forest may become re-established. Secondary forests, degraded lands and other human impacted areas comprise an increasingly large proportion of Gurakor's lands as elsewhere in PNG but receive little attention although there is a growing need for improved scientific understanding on which the effective management of impacted systems could be based.

When mature forest is disturbed by burning or clear-felling, a secondary forest will quickly develop in four stages, if no other disturbances occur and if the soil is not too impoverished:

1. First the bare soil will quickly be covered by broad-leaved, light-loving pioneer plants, especially garden weeds, grasses and abundant.
2. Some fast growing light-demanding shrubs and trees with rather soft tissues including euphorbs, tall gingers, ferns and wild bananas, will develop.
3. The plot will convert to very dense early secondary forest with more shade tolerant species, tree ferns and woody climbers.
4. The late secondary forest then takes over, still different from the primary forest, smaller in size and poorer in species. Pandanus, palms and epiphytes initially remain scarce, but it slowly becomes more varied and a ground cover of shade-tolerant herbs develops.

In recent years, the fallow regrowth in some parts close to the settlements has been reduced to tall cane grasses (mainly *Saccharum*), Kunai grass (*Imprearata*), Golgol (*Alpinia spp.*), several Compositae, Euphorbiaceae, bamboo, and low shrubby regrowth with the dominating non-

indigenous species, *Piper aduncum*. These species are all indicators for human intervention (cf. PAIJMANS 1976, 80p).

Value of crop land and secondary regrowth

The whole secondary zone which is derived from clearing for gardens combined with the protection of tree seedlings during weeding has a high interspecies diversity. As the traditional AFS is truly polycultural, it exhibits a high degree of interspecies diversity incorporating a wide range of cultivated indigenous and introduced species and also wild or semi-wild species. The numbers of species are hard to estimate but certainly include over 100 used or cultivated plant species besides other plants and animals. There is, additionally, a high degree of intraspecies diversity for most traditional trees (i.e. breadfruit, galip, coconut) and non-tree cultivars (esp. bananas, taro, pandanus, sugar cane, hibiscus) and for many recently introduced ones (pumpkin, papaya, avocado, and a range of citrus fruit species). Some of these local cultigenes or even species are rare today because they are abandoned for their lower yields, bitter taste for instance (e.g. Bitter yam) or when they are infested by viruses (esp. taro) and other diseases. As the patchwork of different regrowth stages and mixed cropping reveals a great diversity, complexity and relatively low levels of human influence[20] compared with permanent cropping, the alternating garden and fallow plots are very valuable. However, it has to be recognized that many plots have already suffered under significant loss of these values due to intensification of land use, soil degradation and dominance of invasive species (cf. chap. 3.2).

Ecological value

Land under shifting cultivation provides ecological service functions for soil, water resources and climate similar to forests when properly managed. Secondary forest communities can in some aspects be more valuable than primary forest due to the reinvigorating functions of fallow vegetation that make shifting cultivation possible. However, secondary forests today do not make up large proportions as in traditional systems with up to 90%, so that the reinvigorating functions are significantly reduced. The high intraspecies and interspecies diversity ensures a high stability due to differential resistance to pests and diseases, tropical cyclone damage and drought and due to more evenly spreading yield distribution and seasonal surpluses. Differential ecological tolerance of the reinvigorating functions ranges in terms of adaptability to different soil types, shade, and hydrological regimes.

Economic value

Not only cropping land with its great variety of cultivated plants and important function for subsistence and surplus production for cash income, but also jungle regrowth provides manifold direct economic benefits. Garden fallow land presents manifold uses of wild plants and remaining cultivated crops. In other words, not only does the temporal alteration of forest fallow with

[20] It is meso-hemerob in the stage of secondary regrowth up to euhemerobic when cultivated (KOWARIK 1988).

cultivation make gardens productive, the successional stages with their secondary communities themselves are valuable for sources of food and materials. Secondary regrowth can serve as a foraging zone for domestic pigs and as a hunting ground for men who pass through it daily on their rounds, provide fodder for livestock and thus offer sources of precious meat. These and other examples below show that alternating garden plots and their various stages of secondary regrowth are of very high economic value and bring about many unrealized potentials.

Socio-cultural value

Garden plots and fallow land have many traditional crops and other plants for ornamentation, healing, ceremonies, construction purposes, handicraft, etc. that are still of high spiritual value. The dynamic shifting cultivation system itself, which leads to the mixed vegetation pattern, with practices developed over millennia and with components that are only typical in a small region, is very valuable for the villagers. The diversified farmed land and its various stages of secondary vegetation dissected by creeks and inhabited by many animals additionally has a high recreational value for people from cities or overseas and for the villagers, too[21].

2.2.3 Coffee plantations and polycultural orchards

An exception of the ever-shifting pattern of cultivated and abandoned gardens are the permanent blocks of robusta coffee with leguminous shade-trees, *Leucaena leucocephala*. The average size of the coffee gardens is small, consisting of between 150 and 250 trees on garden lands near the homes (cf. fig. 10). In addition, a great variety of useful trees, palms and other perennial plants are scattered over the present or abandoned centres of settlement like permanent groves and as adjuncts to the wider village AFS (cf. map n°3, fig. 10). Most of them are fruit trees, coconut and betel-nut palms as well as ornamental and medicinal plants.

coffee plantation

Fig. 10: Aerial photograph with the view on two coffee plantations and tree gardens within the settlements of Gurakor, 1997.

Value of permanent groves

Polycultural orchards and coffee plantations can have similar ecological service functions as secondary forest stands due to their deep-rooting, permanent and often multi-layered character

[21] For instance, locals mentioned that walking with friends and relatives long distances to work the land, sometimes living in temporary shelters for some days far away from the rest of the clan or community, is not necessarily seen as a burden, but in part as a diversion or recreation.

(cf. above). But since those plots are on flat favourable sites rather than marginal land they are not of such high value as most remaining forests. Particularly intercropped *Leucaena* and other deep-rooting trees help to improve soil, provide shade and a good microclimate, an important factor for understorey trees and shrubs and also for the people or animals. Thus, ecological benefits of the present permanent groves are high but not of that significance as with forests.

The direct economic value of polycultural orchards is high due to the constant supply of highly digestible food, materials, medicine, local cash crop, etc. (cf. app. 3 H-L). Better husbandry in the vicinity of homes, improved and recently introduced cultivars allow higher yields and thus economic benefits can be very high. Coffee is a source of monetary income for few families, but at the present coffee gardens are stable with little replanting or expansion, and prices have declined so that it is sometimes hardly worth harvesting and processing the coffee beans.

The growth of Robusta coffee in permanent groves was only introduced in the late 1950s by the colonial government[22] and has not reached high significance in Gurakor, so that it has no special socio-cultural value like in the highlands or other regions where it has been very successfully adapted to the system. However, permanent groves often serve as refugia for endangered or culturally-important traditional species, as well as avenues for the introduction and testing of new imported species so that permanent groves can also have a high socio-cultural value besides their ecological and economic importance. Only due to their small proportion they have not such high significance at the moment as other biotopeic structures described above.

2.2.4 Kunai-grassland

In Gurakor, in contrast to many other settled areas, permanent patches of kunai grass are still relatively small but are continuously expanding. In New Guinea, Kunai (=*Imperata spp.*)[23] forms pure single–species land when managed by fire and in areas of deforestation and erosion at lower altitudes like in Gurakor, it also forms successions with tall cane grasses interspersed by few tree species like *Piper aduncum* or useful fruit trees that have been left standing (cf. fig. 11). Except for the fruit trees, these species are all indicative of degraded sites. The fertility requirements of Imperata appear to be much less than that of other vegetation and it will colonise soil which is acidic, strongly weathered and low in nutrients. Only when subject to prolonged shading by other plants it thins out and it is eventually replaced by shade-tolerant vegetation.

Value of grassland

The conversion of large tracts of closed forest to grasslands through processes of shifting cultivation and continued burning is detrimental, because forest is considered to be innately more

[22] TOBIAS senior (1997) said that in 1954/56 an advisor of the Dept. of Agriculture persuaded and taught villagers how to plant coffee gardens. In PNG Pidgin English these advisors are known as „didiman"

[23] Both the pandemic genus *Imperata*, found in the tropics of all continents, and *Imperata* grassland are known as 'Kunai' in PNG Pidgin English.

productive and valuable in an ecological sense than the grassland. The resultant biotope is classed as 'wasteland' by both government and external agencies, because the soil under Imperata is degraded and it is not an integral part of the agricultural system and thus 'unusable' because it requires rehabilitation (cf. TURVEY 1994, 9p). Traditionally, Kunai is used for roof thatch and in some cases it is even cultivated for this purpose. Besides it can be used for a low-quality paper making and as mulch.

Fig. 11: Grassland with interspersed breadfruit trees and Piper aduncum shrubs on slopes in the background, Gurakor, 1997.

2.2.5 Gallery forests and riversides

Small forest strips along creeks, especially where dissected fan surfaces form steep irregular slumped ridges occur, are an exception in the otherwise almost completely cultivated valley, whereby the slightly undulating banks along the larger streams like the Wampit River and Gurakor Creek are considered to be the best sites for gardening and are therefore included in the shifting cultivation system (cf. title page). On sandy and rocky banks, shrubs with horizontal branches spread in the direction of streams. They are flood-resistant, tough, and firmly anchored by a wide root system. Also included are ferns, grasses and several more or less permanently inundated aquatic herbs. As quite small areas along rivers and creeks in Gurakor are inundated, only small fragments of swamp forest with sago palms can be found. Prawns (shrimps) and other small shellfish live in Gurakor's creeks and rivers.

Fig. 12: Gallery forest along Mumbong creek, Gurakor 1997.

Value of riverside forests

As the community depends on surface water from creeks and rivers for drinking water, washing and cleaning of dishes, vegetation along creeks and rivers particularly on steep ridges, but also on gentle sloping banks that may be periodically inundated is very important for the quality and refreshing temperature of the water, of which Gurakor people are so proud. The vegetation does not only provide shade and accelerate water purification, it also mitigates siltation, impacts of

floods and erosion (cf. fig. 12). The reinvigorating power of the vegetation due to good water availability on riverbanks is also of indirect economic value for food production as it allows shorter cropping cycles. Although it often does not reach high ages, the original vegetation seems to be well adopted to forest clearing as similar disturbances also occur naturally through landslides or flooding and as it regenerates quickly. Small sago stands and some nut trees that prefer swampy or riverside places provide food, and like forests or secondary growth gallery forests provide many other material and immaterial values for the population.

2.2.6 Potential of some species for subsistence and marketing

Altogether 1035 plant species are recorded in PAIJMANS (1976) as used for a variety of purposes on New Guinea, 500 of which are grown for food (cf. FRENCH 1986)! Also in Gurakor, crop diversity is very high and therefore a more complete understanding of the breadth of plant resources has to be given. An inventory of some present and potential food, fodder, medicinal, ornamental plants and multipurpose trees that are available in the forests and cultivated lands or that suit the natural and socio-economic conditions in Gurakor was made. 172 species are listed in app.3, 138 of which were seen in Gurakor and 34 that were not found but are very likely to be present and exist in the region. As far as available information is given about the origin of these species because indigenous plants shall be promoted, whether they have weedy or invasive behaviour that may or does threaten biodiversity and about local or regional varieties or wild forms. Demands to light, to soil and water availability, time of planting, and spacing are important to see which potential the different plants have in different environments. Ecological service functions, nutritive value or socio-cultural and economic benefits of listed plants are noted since they are relevant and known. In the following section more hints are given on useful groups of plants and their potentials for AF, as well as animal resources.

Staple food crops and other important energy food

The most important staple food plants in PNG´s culture and climate are rhizomes, tubers and root crops (and not rice!). At least 6 species are cultivated in Gurakor with sweet potato, various taros, yam species (cf. app. 3 A) and cassava with many different cultivars. Other staple crops include a range of diploid, triploid and tetraploid bananas, which are eaten unripe and cooked or others raw when ripe. Breadfruit and coconut are other important energy food crops and to a small extent sago which swampy places suit. Maize has grown in importance, whereas upland rice that suits Gurakor´s climate, too, has not reached acceptance among people in Gurakor[24] and most other places in PNG, owing to the unusual and labour intensive cultivation practices.

Many of these important food crops were introduced centuries ago having a long tradition in PNG and now they are represented by many local and regional varieties. The most significant

[24] There was only an old 'didiman' who made some attempts to grow upland rice in Gurakor, but neither he himself showed interest in teaching others in this practice, nor did villagers try to learn it.

example is sweet potato, which was introduced about 400 years ago (HALSTEAD 1996, 39). This faster growing and less demanding species replaces taro, which needs at least 6 months to mature, and banana which needs up to one year, as the main food crop in the study area. More recent introductions are Chinese taro, cassava and maize. They fit well into the mixed cropping system and cassava has a very high potential in AF as it can make P available (a limiting factor in most of Gurakor's soils!) and is the most productive tuber plant[25] even on poor soil. Its tubers can remain for years in the soil and provide famine food. An advantage of the quite care-intensive yam is, that is very digestible and it can be stored for weeks or longer in contrast to most other tubers. Chinese taro is more productive, but not as favoured as traditional varieties with better taste and consistency.

Cultivated vegetables

Up to 27 important vegetable crops can be found in Gurakor that are either indigenous, aboriginal or naturalized post European introductions. Most traditional cultivated or semi-cultivated vegetables are inner stems, flower stalks of grasses (e.g. fig. 13), bamboo shoots and particularly leafy green vegetables of annual, herbal or perennial plants (app. 3 B+C). Long pitpit, maybe a mutant derived from sugar cane is possibly indigenous to PNG. If the traditional garden types of this very old, nutritious and tasteful vegetable are neglected and not propagated vegetatively, they seem to die out because they usually do not produce seed (GOELTEN. 1990, 107).

Fig. 13: Hailands pitpit on Nendacuem, shown by women from Gurakor, 19.6.97.

There are introduced but also traditional leguminous vegetables with very high nutritional value in the protein lacking diet of villagers and high potential for AF on impoverished soil (cf. app. 3 D). Whereas today peanuts are widely accepted by farmers many other imported leguminous vegetables remain unused or are not widely distributed and also traditional ones are rare although they may bear an even greater potential than high yielding varieties of soybean or others. The best example is the tropical Asbin (Winged bean) that is grown in PNG and Southeast Asia (fig. 14). Not only does it produce more nitrogen than most other leguminous vegetables and is generally free of pests and diseases, this climbing bean is also unique in that practically all parts, even the tuberous roots are edible and high in protein and vitamins. Oil and flower can be made out of the seeds and they can be stored when dry. Due to

[25] It can produce ten times as much starch as maize on the same piece of land

high nitrogen levels in all parts of this plant, it makes a good green manure, cover or restorative fallow crop (cf. ANONYMOUS 1997a).

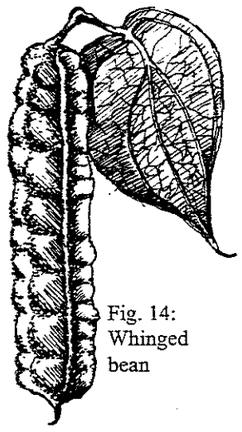

Fig. 14: Whinged bean

Other introduced vegetables like choko, onions, pumpkin different gourds and since recently carrots, tomato, etc. can enrich the daily meals, and provide sources of cash income when sold on regional markets. Some of them need better husbandry to grow well and are often of lower nutritious value than traditional vegetables (cf. app. 3 E).

Cultivated fruit crops

Perennial non-woody fruit species consist of a wide range of bananas, pineapple, papaya, water melon and sometimes climbing passion fruits, which are important protective food as they provide very high values of vitamins. Most are introduced, except for some banana varieties, but already well adapted to the system. The same applies to many fruit trees, especially citrus fruits, mango, avocado. The last has very high protein content and up to 32% fat, which makes it one of the most valuable fruits of the tropics (BÄRTELS 1996, 294). The introduced Guava might also be of high nutritious and medicinal value but it is a serious invader in semi-natural or even natural habitats, too (CRONK, FULLER 1995, 128). Some indigenous nut trees, such as galip-nuts, or pomelo, rose apples and the oceanic lychee[26] are in few cases planted during the cropping cycle or within the settlements but are more semi-cultivated or wild than cultivated and will be described in the next section.

Importance of wild and semi-domesticated food resources

Agriculture is a major source of food intake of the villagers, but in Gurakor, where extensive stands of primary and secondary forest remain wild food sources provide a significant input to the food intake. Depending on the season tubers (wild yams), ferns, berries, fruits, nuts, leaves and shoots of a large number of higher plants (app. 3 F+I), mushrooms and honey can be gathered for their food. Animals like possums, tree kangaroos, wallabies, birds, snakes and other reptiles, fish, eels, freshwater prawns, grubs and insects are highly valued for their meat and in many cases but for their fur, skin or feathers as well. Rural people consume hundreds of species of edible plants and game as part of the regular diet, which are never or seldom found in market-place stalls and which help to overcome food shortages with animal products or due to their seasonal complementarity with many agricultural crops. Additionally 'emergency food plants'[27] are only consumed at times of natural calamities and droughts (e.g. El Niño) whereas in normal times people tend to be very selective about species, varieties and parts consumed. That is why from the many species available, merely a fraction is used for food.

[26] = *Pometia pinnata* with its leaves being used as mulch and green manure in yam cultivation in other areas.

[27] e.g. even the bark of *Acacia arabica* and *Leucaena leucocephala* can be ground into fine flavour

Such constant energy resources (without replanting) of breadfruit, wild fruits and nuts are of particular importance, given the increasing food dependency on imported food, which is a serious economic and nutritional problem particularly in times of droughts. E.g. the wild fruit of Pangi provides about 10 seeds, measuring about 2-5 cm each, with kernels rich in fats and protein and edible after roasting or other processing[28] (fig. 15). Semi-cultivated fruit trees, nut trees, leaf-providing trees and sugar cane are some of the best sources known of vitamins, minerals, fibre, and other micronutrients, often with higher contents than introduced crops (app. 3 C&+F). Apart from being nutritionally important, wild products constitute low-input and low risk cash crops. Most of these foodstuffs are obtained from public lands, free of charge and usually require only a small labour input.

Fig. 15: *Pangium edule*, a wild food resource in Gurakor's forests, 1997.

Many of those various indigenous trees, shrubs or other species occur naturally in forest environments and are rarely 'cultivated', nor are efforts made towards 'domestication' of wild animals, improvement through selection and breeding. Such wild species, however, offer a hitherto unknown potential for improvement in agroforestry as they may be a source of new economic plants and animals, and due to advances in growing and breeding, also practicable on a local scale, it is increasingly possible to find new varieties. Today's lesser known crop can become tomorrow's breadwinner in many countries (cf. NAIR 1989, 541pp). For instance, there are, according to GENO (1996), over forty indigenous plant species with an edible kernel in PNG, eleven of them classed as being important in village agriculture. Of these six are seen as having potential for commercial development and out of these cut nut or pao, galip nut and okari are suitable to Gurakor's altitudes. All species, particularly galip, are marketed locally and there is growing interest on the international market. Galip is popular among outsiders and expatriates, and the prospects for its commercial development are considered to be excellent. Likewise the tasty and oil bearing *Pandanus conoideus* (Marita) could become an important cash crop.

These mentioned, plus a wide range of other supplementary crops and fruits (app. 3 H, I), no matter whether they are domesticated, semi-wild or wild, have wide implications not only for the nutritional status and economic situation of the local population, but also in conservation of natural gene resources as well as their adaption to present and future human needs.

[28] Additionally the seed shells of this traditional wild food resource used to be of significance in singsongs as jingle-bells, in some regions oil is extracted for cooking, to provide light or for making soap, and the leaves are used to preserve meat.

Nitrogen fixing and multipurpose tree species of agroforestry potential

In general trees may be considered suitable for AF if they complement and support rather than compete with interplanted crops and are suitability to end uses (NAIR 1989, 304). Many of the nitrogen-fixing, fast growing, multiple-use tree species fall in this category. Out of over 2.000 species that satisfy these characteristics, only a handful of genera have been tested and used in AF, such as *Leucaena, Albizia, Gliricidia and Calliandra* (ibid., 305). The rest, especially species indigenous to PNG, remain untried and therefore their potential is unrealized. Indigenous nitrogen fixing tree species (=NFTS) are likely to fit the ecological conditions of the site and to thrive and be productive under conditions that are, at times extreme, e.g. during excessive droughts, due to severe erosion and nutrient-depletion. Besides the better known introduced NFTS, indigenous ones are included in app. 3 J, as they are more appropriate in PNG AF due to their better availability and because they do not threaten biodiversity like the invasive introduced species of the genera *Leucaena, Lantana, Crotalaria* and *Cassia* (cf. CRONK, FULLER 1995).

Medical importance of herbs and trees

The importance of medicinal plants in AF used by many rural and urban people, most of whom have no access to or could not afford imported medicine, not to mention their frequent unavailability, misuse, and, in some cases, doubtful efficacy, cannot be stressed too strongly. It is underlined by the high numbers of medicinal plants found around homes, on cropping land and in forests. There are about 332 species of medicinal plants recorded by PAIJMANS (1976), known and used by local people in PNG but usually not sold on markets. Also people in Gurakor still cultivate and search for medicinal plants many of which are trees or shrubs. Some medicinal plants of Gurakor and their local uses are described in app. 3 M. Due to the great variety of medicinal plants in PNG, varying uses and knowledge about them in different regions or even villages it has often been difficult to find out their scientific names. Therefore some of them are only written in the local language (=Keyang) but not with their scientific or English equivalents. If these medicinal plans are nourishing, sheltering and healing villagers in Gurakor and elsewhere, they must have economic value. Some of them have already been tested for important chemical constituents but precede further exploration.

Valuable spices, narcotics, stimulants, ornamentals and magic plants

Indigenous spices such as ginger, nutmegs and cinnamon and some imported ones like chillies, cardamom, black pepper, vanilla have high value on international markets. Socio-cultural and high regional economic value as cash crops is owed to light narcotics such as betel-nuts, betel pepper and tobacco, that are frequent components in subsistence gardens. The magico-religious or spiritual importance of trees and plants or plant parts for ritual and magical purposes, decoration and body ornamentation, is another considerable aspect of Melanesian AF. Species may serve as symbols for planting cycles (cf. chap. 3.3.2), or ornamental, sacred or perfumed plants are used for traditional sing songs (dances) and to a declining extent, for ceremonies and magic (cf. app. 3 L). Such flowers, herbs and trees additionally serve to create pleasant surroundings.

Potential of tree and other species for raw material

Besides purposes mentioned above forests and secondary regrowth provide miscellaneous wooden materials for building purposes, tools, weapons, and artefacts, material for clothing and handicraft, cordage, dyes, poisons, scents, oils, and an almost endless range of utilitarian products with subsistence and commercial value. Many genera and species are multipurpose and some, such as coconuts, bananas, bamboo, sago and pandanus, provide both food and material needs. For example bamboo cuttings, banana and tall ginger leaves can be used as clean surfaces for food preparation, wrapping material or dishes. Edible and non-edible pandanus species provide leaves that are used in plaited ware such as mats, thatching, hats, baskets, and other items of cultural or economic importance. People in Gurakor often construct their houses with woods that are not sold internationally, or even locally. Bark from tropical genera such as *Ficus, Hibiscus* and many others used to be material for clothing and today it is for example sold as book covers. Fibres from these and other trees *(esp. Gnetum genmon)* serve for twisting ropes and for the manufacture of traditional string bags. There are many other non-timber products and extractives like fatty oils, resins, latex for rubber production or toys, dyes like annatto *(Bixa orellana)* and *Bischofia javanica* for food colouring or ornamentation, rattan for furniture and many more that are of local but also international importance for enzymes etc.

Trees and other species for energy supply

Last but not least the forests, fallow land and AFSs provide a great potential for fuel- and firewood, a very important factor in a subsistence society, where a lot of people already have to walk long distances to collect their firewood. Another energy resource and alternatives to petroleum could be palm oils and other oilseeds, that are estimated to give renewably up to 90 barrels of ethanol per ha, three times as much as sugarcane (DUKE 1992, 55).

To conclude, not only forests but also AFSs are ultimately linked to high biodiversity. The indigenous AFS is highly dynamic, and the boundaries between domesticated plants and animals and wild species are constantly shifting. Additionally to the many uses they already provide today many underexploited wild plants and animals of little or no current market value could eventually provide significant employment and income in the future and enhance the economic and ecological stability of future AFSs.

2.3 Human resources and socio- economic aspects

The following description and evaluation of socio-cultural and economic circumstances or human resources in Gurakor that may influence future AF, shall give a better understanding of strengths and weaknesses of the local situation and shall avoid development taking a inappropriate and unsustainable course.

2.3.1 Population growth, labour, income and urbanization

In Gurakor, the population censuses of 1980 and 1990 have indicated a doubling of the popula-

tion from 295 people in 1980 to 645 in 1990 (NSO 1993). This is an alarming growth rate far above the national level, which is 2.3% per year[29].

Fig. 16: 'Human resources' in Gurakor, 1997.

Traditionally, the entire indigenous population was supported by the subsistence economy based on agroforestry. Although there has been a considerable decrease in self-sufficiency and development in the cash economy during the 20-year span, the majority of the population in Gurakor still make their living on traditional subsistence production, hunting and harvesting of forest products. Some amounts of betel-nut and fresh food are sold on the local or regional market and in very few cases coffee production or small-scale gold mining are additional sources of income. Some of the villagers earn wages by working in their own community, in the Conference Centre nearby or elsewhere in centres like Lae or Bulolo.

Consequences of population growth for agroforestry and society

Large numbers of children have lead to repeated subdivisions of the family farm land so that present sizes cannot feed one family under traditional alternating cultivation. Fallow periods are drastically reduced and young peasant farmers move up on marginal steep lands which are inappropriate for agriculture and have to endure long walking distances to their fields. Insufficient surpluses are produced for sale so that cash income is very limited and as prices and terms of trade have declined over the last decades and land is getting scarce, there is little hope that it will improve under the present AFS. Most people are poor by the standards of developed countries and there is a growing income gap between urban and rural areas. On the other hand many people in Gurakor are not accustomed to calculating the total yield of a certain food crop sold on the market or the time they spend hunting or working in the garden every week or even every month. When money is earned by selling agricultural products, it is often spent the same day on purchased imported food, cloths and processed products.

Problems concerning low cash income

Hence, villagers have little ability to invest in improvements in AF and they have little ability to buy essential farm inputs like nutrients to compensate reduced fallow time. This is a contributory factor to land degradation. As there is no cash, to pay school fees for all children, other training requiring money or needs like health care, able members of Gurakor search for off-farm

[29] Apart from recent changes like the introduction of malaria control and modern medicine, the relaxation of customary restrictions on sexual activities seems to be the major cause for this rapid increase in resident population.

employment. Grade 6 leavers of the rural school and even those with limited educational standards have the only desire to seek employment in a city aspire the status and material wealth that was achieved by a small elite the Australians developed in PNG. This leads to further urbanization, although urban and other employment opportunities are unlikely to rise at a rate similar to the rate of urban expansion or the general population growth rate (cf. ALLEN 1992, 59). Insufficient income generating activities in the cities and rural areas for young people are certainly a major cause for crime and violence around Gurakor (cf. BERGMANN 1996, unpub.). A frequent topic at Gurakor's village meetings or in the village court these days is, the increasing theft of quite large amounts of food crops in the fields.

Problems of labour shortages

Since the lack of rural development forces many young people to flock to urban areas or because they are not willing to help in AF after having received education, some households suffer from inadequate labour supplies in AF despite increasing populations. Labour productivity can hardly be raised through technology, as neither the economic nor the environmental situation can allow it, so that labour is critical for food security. As a consequence of labour shortage many old people and particularly women, have no option but to overcrop.

Men have abandoned their own male cult, and much more in their ritual life, very rapidly after exposure to Christianity. Hunting is quite reduced and there is no need for protecting or fighting against other tribes anymore. Still, males often see their duty only in slashing and burning according to their tradition, whereas most of the planting, maintaining and harvesting are women's duties besides their household work. As a consequence men do often not have 'full time' jobs and spend a lot of time on amusements. Additionally it has to be considered that in PNG culture men seem to attribute a greater value to leisure time than most Westerners and that they may think that it is not absolutely necessary for a worthwhile life to buy many consumer goods and thus work until they could afford them. Moreover, what is associated with leisure in the West might be productive in PNG societies. For instance visiting relatives or neighbours is an economic necessity because at crucial periods their help with labour or food may be necessary. Although this might have been necessary in the past, it has to be questioned whether it can still be afforded under population pressure, dwindling natural resources, labour shortage and thus the difficulty to produce sufficiently.

2.3.2 Community organization and social structure

Effective social units in traditional Melanesian cultures tend to be small, based on family, clan and community[30]. The community of Gurakor is divided into three clans which are called Nadandia, Webumpu and Petuke. These are kinship groups, to which membership is recruited

[30] The terms 'groups' or 'communities' seem to be more adequate than 'tribes' to refer to effective social units, in the main residentially defined village or cluster of hamlets (GARDNER,WEINER 1992).

mainly by patrilineal descent as the basis for asserting local political identity. Today there is additionally a distinction into different groups which live in separate settlements and have their own leaders.

Within and between the different households and groups there are complicated networks of responsibility based on the principles of mutual help and income sharing. Work on an individual smallholding is not only done by the members of the household, but by a group of relatives or friends. They will, in turn, help other farmers at peak labour time. However, there is a clear trend towards more individualism and materialism in Gurakor's society. Whereas food, labour or other help used to be given out of duty, or in the expectation of some kind of return, today things are usually sold, even to close relatives (talks with JOHN 1997).

Prominence is achieved rather than inherited and the community is democratic. The daily competition for status amongst men who recognize no asymmetry in their relations to other men gives social life in PNG its distinctive characteristics. It is for this reason that anthropologists refer to PNG societies as egalitarian (cf. SAHLINS 1963) and it does not necessarily include equal rights of the genders.

Traditional groups were not bound to special activities, they were all-embracing instead. But today there also exist other groups or clubs in Gurakor, such as the religious (Evangelical Lutheran and the Seventh Day Adventist) congregations, regional Youth-, Women's (Local Language: Geamsau) and other clubs with their own leaders and organisations.

Some problems and opportunities concerning the social structure

The principal of mutual help has both advantages and disadvantages. On the one hand it is often possible to get work done by a group which could not be achieved by an individual household and such institutions constitute a sort of local social security system. Group work, however, often has the negative effect, that there is little incentive for the individual to excel and thus work may not be that effective. The emphasis on small social units often leads to tension between tribal groups and members often work against each other owing to customary jealousy, suspicion, inter-clan rivalry and local political infighting. This growing lack of inter-clan cohesion was clearly shown during joint activities and congregation meetings in Gurakor.

A positive sign appeared to be the women's club, which is an engaged and constructive parochial institution of Gurakor and neighbouring communities. Yet, within the families or groups women still lack equal rights, although they are the vital forces in keeping the family and community together and contribute significantly to agricultural and other productive activities.

2.3.3 Land tenure and land resource rights

Rights to land and other resources are, like in most other regions, vested in clans or nowadays in groups. The three different clans of Gurakor own all the land with the exception of the government owned motorway. The most important characteristic to recognize in Melanesian

land tenure is, that although land is owned by clans or groups, it is used by individuals, or more precisely households. It must be divided between land tenure rights and land use or resource rights. Resource rights include the rights for cultivation, hunting, fishing, collecting materials or wild food, to built a house and to pass on resource rights to descendants.

Membership of a clan carries with it the rights to use clan land, and in general a person's most important access is to his or her own clan's land. Especially cash crops like coffee are always grown there. Still, in Gurakor the rights of use tend to be very flexible as long as the population is relatively low. Land which is not being cultivated is open to all village residents for collecting fuel wood, building materials and edible plants from the wild or for hunting and fishing. This means these things are also accessible to other clan members sometimes even descendants and people of other villages. Since Christianization, Gurakor has given land use rights to a couple of villages like Patep, Omala, Zenag, Timini, Bupu, to give them the possibility to settle down close to the newly built road.

When an individual has cleared a new piece of primary forest, he and his descendants have the right to use this garden even if it is part of another clan ´s land. In Gurakor, once the right to cultivate land is obtained through clearing of virgin forest, this is transferred patrilineally, in particular to the first born son who divides the land among his brothers. Also this tradition is not as strict as in ancient times. Often relatives and friends from other clans may gain short-term access to surplus land owned by another clan from Gurakor for preparing, planting a garden and harvesting its produce. This right is only a right of use, not ownership, which means he may not be allowed to plant trees or palms in case the owner himself wants to use his land again later.

One individual from a clan cannot dispose of any area or parcel of land or alienate any existing resources (rather than planted ones) from that land of his own initiative. It is still the clan that has final control over the land, e.g. to sell rights to companies for exploitation of gold or timber.

Purely individual possessions are only those that are required through one's own labour like houses and crops. This tradition also applies to economic palms, coffee plantations, trees and vines. They belong to the person/ household who planted them, provided they are looked after and maintained and they can be inherited by the planter's descendants.

Opportunities and problems of traditional ownership

Although there is a growing gap between the modern monetary sector and rural areas leading to growing intragenerational inequity and crime in PNG, traditional land-ownership combined with social bounds inside of kinship groups principally ensure the satisfaction of basic needs for all villagers, even if they had lived in a city or somewhere else for several years. It is still ensured through relatively liberal land use rights at the moment. There is, however, a visible tendency towards conflicts between land user groups with land shortages and truly equal access to land is not given since the traditional tenure system does not give women sufficient rights for land. Despite their important role in ecological and agricultural rehabilitation and enduring food secu-

rity, women do not have direct rights to land and their access to it is being curtailed by titles being provided by men only[31]. This is particularly hard for widows and unmarried women.

A dilemma may arise with land shortages in the future because knowledge of boundaries and land tenure rights are only passed by word of mouth from one generation to another and there is no clear demarcation of land properties fought out yet even between different villages. There are only few elder clan members left who can tell and distinguish most land titles and their relation to land. Thus an attempt to roughly titillate the currently cultivated land according to different clan members' descriptions (talks with TOBIAS, JOHN, JALING and NIKODEM 1997) is presented in map n°3 whereas clear borders must be determined by the villagers themselves.

Collective land ownership does not have to reduce efficiency or productivity, as often overrated by economists[32], because farmers in PNG have their own land use rights, and crops or other economic plants can be owned individually. A more urgent problem these days is land fragmentation. One family or individual might have a number of small parcels scattered over the whole area of Gurakor's lands, which makes good farm management practices difficult. Under collective land ownership this obstacle could be solved more easily as if land is owned individually.

2.3.4 Local skills, knowledge and openness for innovation

Many aspects of folk knowledge for working with nature rather than against it have been honed over millennia. Local people still co-evolve with their environments and have acquired considerable knowledge about the locations and appropriate strategies for harvesting and managing their resources (cf. chap. 3). People in Gurakor are familiar with at least 1000 useful species and they endeavour to only use an amount of plants and animals which does not endanger ecological stability on which they depend. Some have specialized skills and knowledge about local medicine, irrigation, recently introduced food crops and two or few others have received formal education concerning agricultural extension but do not share their knowledge.

Problems

Since the in-depth knowledge is limited to forms of shifting cultivation, people are forced to break their own rules under conditions of land pressure. Local farmers, without a doubt, lack the scientific training and know how to develop alternative techniques that are better suited to changed circumstances. On the other hand a lot of traditional knowledge such as therapeutic practices, material products and technical skills have been discarded since colonialism and mission emerged and is still seriously eroding because 'white man culture' is seen as more progressive and desirable than their own Melanesian tradition. Many children and adolescents who

[31] Also access to water is not equally distributed as women have to wash downstream from the men's wash place.

[32] It is more likely that this merely positive force, that tribal groups have any bargain power with outside interests over the use of their land, is seen by western governments and (mining and timber-) companies as restricting their activities. Still tribal landowners have little control over the wider economic forces affecting the development in PNG.

would have formerly been initiated into the customs of their society now do not receive any initiation. Often they have to leave their village to go to school or join relatives who have emigrated to towns. As a consequence traditional uses of plants and practices are often not passed on to the younger generation. When old people die, much traditional wisdom and knowledge is lost. The result is a substantial reduction in the range of natural resources which were formerly valued and consumed as raw materials for different forms of work. Such reduction is certainly a major threat to the maintenance of biodiversity in AF.

Although women play an important role in food production, cultivation, seed selection and providing the main labour in AF, their traditional knowledge is often neither sought nor built upon.

Openness to innovations

First it seemed that many farmers are not convinced of the need for improvements in AF but after later impressions it was experienced that they often did not see the relationship between their needs or wants and development. Many have not fully recognized the increasing inequilibrium of the present system and the pressing need for improvements. ALLEN (1989) states that the PNG shifting cultivators have a deep knowledge of the fallow succession characteristics, and they are willing to accept innovations if sufficient incentives are provided. Interviews and resonance on community meetings in the village showed that some farmers are just not willing or ready to carry out some single practices like labour intensive production of compost and handling of pig or other manure. However, pupils of the Training Centre (=ATS) or the workforce in HDC, Bundun, are used to overcoming such initial antipathies soon. Others are sceptical concerning permanent cultivation without fallow land. Since the first trainees successfully and confidently absolved their course at ATS, there has also been growing interest among Gurakor villagers to take part. This shows that farmers do not take risks easily because they rely for most of their subsistence on the produce of their smallholding but that they are by no means generally conservative or 'primitive' or adamantly unwilling to improve their lot. They are neither opposed to increasing their yields or cash incomes, nor are they hostile to planting and caring for trees on their land- provided technology changes and improvements fit into their problems, priorities, beliefs and aims. Like in other cultures, elderly people tended to leave innovations to the younger generation. Other aspects that could influence people's attitudes are mentioned in the following chapter and are known as 'cargo cults. Whether farmers are innovative or not, the danger is that the need for change will be recognized too late and government too is insufficiently aware of the problems, or at least acts if this is the case. On the other hand it has been shown during the last decades that cultural constraints are in no sense permanent and, given the right environment they can (often too) rapidly change.

2.3.5 Culture, local customs and their influence on agroforestry development

Beliefs and religion

Not only the physical environments in which PNG farmers live are extremely diverse but also

socio-cultural conditions and their resulting farming systems. If 'culture areas' are equated with language families, then PNG has approximately 180 of them (with over 750 different languages). Cultural diversity influences the farming system, e.g. in beliefs about food, pig management practices and the influence of male/female roles and their contribution to labour supply. Nevertheless, with relatively long (since 1920ies) and intensive contact with western Christianity in Gurakor warfare against neighbouring tribes has been stopped and life style patterns, attitudes, beliefs like traditional animist thoughts and behaviour altered. Other influences on Gurakor from outside include the involvement in the cash economy and access to markets since about 1950, which changed the traditional system of exchange and reciprocity (interview with JOHN 1997).

Although there is progressive alienation of the rural community from 'traditional values', there has been a cultural revival, in part for the entertainment of tourists on culture shows or public events and in part for the people themselves. In some other villages of PNG there has also been a mending of other traditional customs like the use of local medicines.

Sacred sites, restrictions of land use as 'traditional nature conservation'?

A positive recognition of biodiversity values is included through the maintenance of 'sacred sites'. For example in a special area of the Nandandia Clan burning forest is tabooed in order to conserve flying foxes and other bats which live in a grove. There are other sacred sites which are of historic or spiritual significance that can not be disturbed or even entered and thus provide a high potential of nature reserves in a more and more intensively used landscape. Customs and practices, like shifting cultivation within a fairly well-defined area of secondary vegetation, helped to remain the ecological equilibrium for ages. Only recently, villagers have begun to encounter the ecological limits of their economic customs in AF through the unsustainable shortening of fallow periods. Despite the existence of sacred sites and sustainable practices, it is hard to say whether or how these perceptions and evaluations are based on a special sense of traditional human ecology like in Western ethics or politics of nature conservation. Certain other features of traditional social organisation, like the small size of corporate groups, strict traditional birth control in the past or the slaughter of domesticated pig herds in Gurakor, would have had the unintended effect of preserving scarce natural resources or restoring some form of ecological equilibrium. Such 'accidental' outcomes which might stem from a combination of utilitarian and spiritual motives, can sometimes exhibit what seems to Westerners like nature conservationist motives.

The bush spirits associated with significant natural species or unusual natural phenomena (masalai) were normally regarded as erratic, dangerous, and amoral creatures, worthy of fear but not respect. This explains why people are nevertheless prepared to sell their timber rights, to turn those 'sacred sites' into money and thus 'sacrifice' it to the spirit of 'development' instead of inheriting a state of mystical harmony with their natural environment (cf. FILER 1994).

Cargo cults and sustainable development?

It is necessary to discuss traditional attitudes to goods and economic exchanges. Some may argue

that economic growth in traditional societies is dependent upon major changes in the norms and institutions of such societies that may inhibit change. This is not the case in PNG societies, where materialism is common and the emphasis on individual achievement is so marked. Ambitious men in traditional PNG societies sought wealth by managing the use of material goods, and the style of these so-called Big Men has a direct parallel with that of successful entrepreneurs in modern economic societies. However, often profit is not the motive for Big Men, but prestige. Money is not used as a store of capital but as a medium of exchange. A consequence of this attitude is that, throughout PNG, many small businesses, like storekeeping, have failed, by European standards but not necessarily in the view of the owner, who has achieved prestige through a network of exchange and gifts giving.

As McSWAIN (1977) has pointed out, such 'storekeepers' may be bewildered by their constant economic problems, and many realized that their stores were not functioning in the way that expatriate-owned stores did. But they may explain this difference in terms of the old suspicion of the cargo cultist, that the Europeans had access to important deities and rituals, and that complete success would continue to elude them until they, too, knew these secrets.

Today, despite a decade of major economic change, cargo cults are still significant because they reveal a major misunderstanding of the real nature of development and the modern world. If economic changes or opportunities are constantly interpreted in magico-religious terms, there is the danger that they may be put at risk (LAMB 1990). Such beliefs are obviously inconsistent with the principles of planning for sustainable development in any form. Once people's desire for 'development' is so thoroughly detached from what is feasible in practice, their impossible dreams may actually hinder the limited possible forms of material progress. Such fantasies can also be seen as one form of response to feelings of powerlessness and frustration amongst PNG villagers, because the rural population really is excluded from most important decisions affecting their lives and because it has experienced the stagnation of material living standards in the period since Independence. It may seem that customary landowners possess as much power as they need to control development that takes place on their land, but they themselves may deny this own capacity to engage in rational management until they reach that general condition of 'development' which may itself remain forever locked in the closed world of companies and politics (cf. FILER 1994).

Feasts

Feasts used to be a very important component of social life and AF production in Gurakor. Initiations for young men were in conclusion accompanied by a big feast and since christianization, at marriages, at Christmas, when a house is built or for other reasons excessive meals are held. The institutions of excessive feast and competitive gift exchange required the production of a 'social surplus'. Extra gardens were prepared for feasts that sometimes took 2 or 3 days, and the stronger and more prominent men were in Gurakor, the more pigs they contributed. Today, no pigs are raised anymore and other livestock is rare, too. Thus much money has to be spent to buy

pigs for feasts or dowry, which is a contributory factor that traditional marriages have become rare because people just cannot afford it (talks with JOHN 1997).

2.3.6 Nutrition and health problems

Besides heat, heavy physical work loads, a severe burden of (esp. parasitic) infections and lack of effective contraception, it is the uncertain food supply, vulnerable nutritional status that causes health problems[33]. The transformation from self-sufficient subsistence farming to partly commercialized production let to dietary changes. Often the best food is sold on the market and only the 'rubbish' (as they call it themselves) is consumed by the family. Whereas, in the past, farmers used to grow a wide range of foodstuffs, nowadays production is partly specialized. There are usually enough vegetables grown for a daily balanced meal, but they are not harvested due to the long distance of the garden plot. Because of these reasons the food quality is low and the meals are normally unbalanced, resulting in very high incidences of nutritional disorders, especially for the children, but also for the rest of the family. Protein malnutrition due to lacking animal or plant protein production is a major problem in many families and is particularly hard on children in their formative years as well as shorter breast-feeding periods[34]. Often ignorance concerning nutrition and food preparation or sometimes just careless lifestyle cause insufficient intakes of vitamins and minerals, leading to malnutrition, anaemia, and infectious diseases, although there still exists a great variety of traditional food providing high amounts of such nutrients.

In some cases development and higher income led to an increased use of imported grain, particularly rice[35], and when the standard of living is further raised, the use of animal products and thus protein intake increases. Apart from increasing food dependency the problem is that many people in Gurakor seem to think that everything in towns and stores is good and increases prestige. Therefore they often spend their little money not only on imported white rice and tinned meat but also on junk food and soft drinks. People in general have the false notion of western civilisation as being superior to their Melanesian tradition which is leading to a shift from a diet of fresh foods high in fibre, vitamins, and minerals and low in sugar, salt, animal fats to a diet of imported, highly refined foods, high consumption of sugar, salt and unsaturated fats. This trend makes them vulnerable to 'modern' chronic diseases like hypertension or cardiovascular disorders, gout, obesity, and diabetes, to which Pacific people additionally seem to be genetically predisposed (BAKER 1979)[36].

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[33] Causes of mortality in PNG are pneumococcal infections (26,9%), tuberculosis (19,6%), bacillary dysentery (12,7%), septic infections (6,6%), tropical ulcer et seq. (6,5%), enteric fever (2,1%), miscellaneous (25,5%) (LEHMANN; RILEY 1992; 85).

[34] It can slow growth, lower mental performance, weaken defence against pneumonia, diarrhoea, and infections, or cause death. Mothers with malnutrition give birth to lower-weight children and often cannot produce enough milk and among adults it can lower resistance to infections, causes premature ageing and death.

[35] In rural areas of PNG rice consumption increased to 12 % of energy consumption already in 1986 (FAO 1986).

[36] Cigarette smoking and alcohol consumption are contributing factors to the rising incidence of such diseases (THAMAN 1983).

2.3.7 Infrastructure and settlement

No society in contemporary PNG is fully traditional. Since the Second World War, particularly the last 20 years, Gurakor, has experienced rapid social and economic change through the provision of health and education services by government and mission agencies. Also cash cropping (in other areas logging, mining) radio and television, must be presumed to have affected the biology as well as the society of villagers. Still there is no industry or manufacture (only two sewing machines!), no telephone or other modern information system in Gurakor. There are only two or three generators and therefore hardly any power machines or electric lighting. One fridge, which has been used for marketing food in a store, was soon abandoned again owing to inefficiency as the villagers said. Every group in Gurakor owns one of two small stores providing the population with imported tinned fish and meat, wheat, rice, some other processed food, sweets and oil besides soap, batteries and other basic needs.

Settlement and waste

Traditional residential separation of age or gender categories for specific ritual purposes or large communal houses are not common anymore. Besides the centre of the village with two major settlements of the Hata and Lendegho group (cf. map n°1) the Ketimbimbe, Gulgho and other small groups in Gurakor live in several more or less dispersed homesteads. Whereas the centre with densely clustered houses have little space in between them, the dispersed settlements of smaller groups provide ideal space for home gardening (cf. fig. 18).

Today the use of latrines is common but not everywhere in Gurakor. Wastes are disposed in holes, in river systems or just thrown away. A most serious problem for soil and water as the basis of sustainable AF production will certainly become the irresponsible disposal of batteries that will pollute soil and water systems.

Houses built of agroforestry products

The bulk of housing materials are derived from the forests and secondary regrowth. The well ventilated houses are built on wooden posts standing about 3 or more feet above the ground. The walls are constructed of plaited bamboo or these days more and more replaced by longer lasting, timber that is carefully hewn with bush-knifes into fine planks (cf. fig. 17, 19).

Houses are floored with hewn planks, split bamboo or palm. The roofs are thatched and pitched of 'grass' (kunai, golgol, pandanus or sago leaves). Vines from the forest are used to lash the houses together, but are more and more being replaced by nails. The whole village is, in fact, in the process of rebuilding and there is a universal wish to possess a house of the newer type with permanent material and corrugated iron roof but these are hard to afford.

Fig. 17: House and members of the Ledegho group, Gurakor 1997.

Fig. 18: Arial photograph of main settlements in Gurakor,1997.

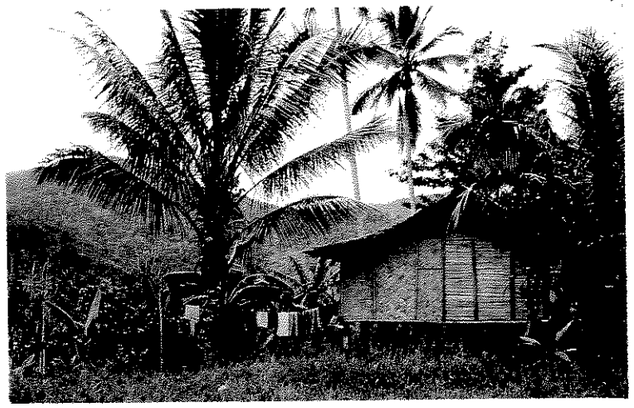

Fig. 19: House of the Hata group with bamboo-walls, Gurakor 1997.

Fig. 20: Woman in Gurakor carrying the heavy load of roofing material.

Transport and marketing infrastructure

Lae is the base of PNG's only major road system, the Highlands Highway, with some sealed[37] branches, one of them leading to Gurakor and further to Bulolo. With this good access, surplus outputs of AF can, easily be transported to local population centres and markets in neighbouring towns (Lae, Mumeng) and there is a constant buyer nearby - the HCD. Path communications within the village, from the village to the fields and to other villages consist of narrow beaten tracks and allow only pedestrians to use them.

Marketing and transport constraints

Within the study area maintenance of foot paths is often lacking when they are not regularly used and are then only viable with bush knifes. This makes even the use of wheelbarrows or other simple transport difficult. Still the need for better physical infrastructure is often over-emphasized. If development is to take place such physical infrastructure has to be accompanied by high provisions of inputs and agricultural extension which seems unrealistic. It is true that a lot of time is wasted on walking and merely women have to carry the heavy burdens on their head for long distances due to lacking transport infrastructure within the fields(cf. fig. 20).. However, it has to be considered whether some of these problems could be mitigated through better allocation of dispersed cultivated land and intensification in the land use system to reduce the distances to the fields.

For regional transport there is only one private car and one Public Motor Vehicle (=PMV) in Gurakor (the second is damaged) despite the good access to the national road system. Thus people usually have to wait hours to get a lift to the markets of Lae or Mumeng on other PMVs, that irregularly run on the road or do not have sufficient space.

Although people sell the bulk of their food production on markets, there is no effective cooperative apart from the family and often they may have to bring many of their goods back again. Others, especially, fruits may remain on the trees until they decay. While there would be a potential for producing fruits as alternative cash crops to coffee for the canning industry, or nuts, spices and raw materials for processing, there are marketing problems that have to be solved first, in particular the cheap imports of these products. This lacking diversification of export and inland trade and governmental agricultural policy has hardly changed since independence (cf. SEIB 1994, 11) and since there is keen competition on all agricultural markets, the dramatic

[37] Only 9 % of national and provincial roads are sealed in PNG (RANNELLS 1995).

decline of world economy prices led to an absolute decline of small scale and plantation production [38].

2.3.8 Governmental health care and education services

Since 1975 PNG is an independent democracy[39] and since 1977 Provincial governments have been a major political force. The 19 elected provincial assemblies have made laws and overseen many government services but they have faced growing criticism for failing to deliver services to villagers. In Gurakor, provision of government services is somewhat better than for many other remote rural locations in PNG since people have the possibility to travel to the district and provincial headquarters to have access to educational and health services if they have enough income and relatives in these centres. Still, there is no aid post in Gurakor, and the services function poorly due to financial crises. About 4 km away in a neighbouring village, Timini, there is a primary community school initiated by the Evan. Luth. Church. The closest middle- and high schools are in Mumeng, Lae, and Salamao, which are 15 to 60 km away.

Lacking extension services and inter-links with grassroots

The moral and political values of PNG's emergent middle class and those of a rural population, which has much nominal if not real control over the use of the nation's natural resources, have little effective contact with state institutions responsible for planning the rational management of those resources. It has been shown that the extension system of the Department of Agriculture and Livestock is ineffective in demonstrating techniques that are useful to smallholders. Subsistence agriculture or AF has never been a priority in government development plans. In terms of work and government finance, hardly anything has been done to improve and to introduce simple and appropriate technologies that will increase subsistence food production (GOELTEN.1990, 208). In Gurakor, villagers could not think of any extension officer or service in the village with exception of coffee or other cash crop initiators, which have been providing advice for a short term only. The advantage for villagers in Gurakor is the close vicinity to the HDC and ATS in Bundun (cf. Foreword) with long lasting cooperation and help.

Problems concerning governmental education

Some people in Gurakor, esp. the older generation and women have not attained any formal education at all and the majority seem to be semi-educated and drop outs of the 6th or 10th grade. Very few have attained complete formal or even higher university education with certificates. The obstacle of schooling in PNG is, that most of the government schools like the one in Timini are modelled on the Australian system and prepare students mainly for higher-level manpower

[38] The absolute decline of smallholder and plantation economy was only avoided through the agricultural stabilization fond (=STABEX) supported by the European Community according to Lomè VI (SEIB 1994, 11).

[39] Until the coming of the Europeans, Gurakor like all the other villages in PNG appeared to be a complete democracy, in which each family had equal rights in village decisions.

needs, but do not provide any appropriate education that reflect adequately the socio-economic realities and local ecosystems, which is AF as the largest sector of local economy. The current PNG curricular suggests that environmental education is either non-existent or remains in an embryonic stage, and in general, environmental issues in PNG's communities, schools and high schools are hardly discussed or taught (SOLON 1993, 12). As a consequence, many of the pupils are bound to go back to their villages or stay in their village without having received any village oriented education. The education system tends to give graduates a superiority complex, aversion and inability to deal with down–to-earth problems and working in the field. The few existing vocational training centres where they could gain practical experiences are unable to cater for the majority of young people (BERGMANN 1997, unpub.). Schools have often created 'job seekers' and not 'job makers', unemployment of school leavers, a drift to town and unwanted change in the traditional way of life and values (GOELTEN. 1990, 223).

Problems with scientific healthcare and some opportunities of traditional medicine

The current pattern of health care utilization in the country is one of multiple strategies, which in the majority of cases begins with family-based diagnosis and therapy, and moves from there to the traditional healer or to the modern aid post or hospital, sometimes going back and forth several times if it does not heal rapidly. Traditional healing continues to be used with medicines made from local plant material or with simple surgery (cf. app.3.M). In some cases sorcery may still be used when serious illness occurs and people will not accept the illness as a natural thing[40]. Still, many villagers seem to seek scientific health care at aid posts and hospitals, and traditional health care is totally refused by some people. However, aid posts and hospitals are at least 15 km away and due to villagers' low budget they usually only see a doctor if their diseases have reached a serious level. Diseases, skin infections and especially wounds are often neglected although many of them could easily be treated with medicinal plants, that contain scientifically valued chemicals. A wise mix of traditional and scientific medicine could provide affordable and efficient health care, but traditional knowledge of medicinal plants is already very scanty in Gurakor not only amongst younger people.

[40] Traditionally the sorcerer may then even counterattack with poison to weaken or kill the enemy, but this was made illegal in the Sorcery Act of 1971 (RANNELLS 1995, 57).

3 AGROFORESTRY PRACTICES AND SUBSISTENCE LAND USE IN GURAKOR - AN ATTEMPT AT EVALUATION

Fig. 21: Schematic drawing of subsistence garden plot and simple farming practices in Gurakor.

3.1 Introduction

In the following sections the traditional AF practices, their recent changes and land uses will be described and an attempt is made to evaluate each of them. The evaluation of such practices and land uses is based on economic, ecological and socio cultural criteria of sustainability that were mentioned in the introductory part. As such an evaluation is again very complex, it has to be limited to an explanation of some outstanding problems and strengths. Thereby it will be distinguished between 'Shifting cultivation practices for subsistence' which makes up the largest part, 'Some special aspects in traditional farming', for example including livestock and small scale irrigation, 'Cash cropping' and 'Hunting, fishing and gathering'.

The following boxes will explain two important terms of the present system in Gurakor to avoid misunderstandings:

BOX. 6: What does agroforestry for subsistence mean?

In PNG, about 70 % and in Gurakor almost all people are subsistence farmers whose objectives are different from those of their counterparts in the industrial world. The latter produce for sale and profit, and if there is no profit they go out of business. In subsistence farming, the use of land is managed mostly by the owner/ occupant and his family and is directed towards satisfying basic needs. Cash crops, including sale of surplus production of commodities, may well be a part of these systems but are only supplementary. A continuous production of food and other products is a must, even if it is unprofitable and uneconomic, because if the farmer stops producing the family will starve. This has major implications for production methods. It means that farmers are not able to take much risk and thus they rely to a large extent, on production methods and techniques developed over centuries, and based on accumulated experience of generations of farmers. These methods usually result in low but stable yields.

Traditional patterns of subsistence in PNG are –like everything else-diverse but all have in common that aspects of living such as forestry, agriculture, housing medicine, or tool making were not compartmentalized into economic sectors. Instead they were part of an integrated agroforestry system (=AFS) tailored to the environmental conditions and material needs of each society (cf.. CLARKE, THAMAN 1993, 17).

BOX. 7: Shifting cultivation - a kind of nomadism?

The term 'shifting' can lead to confusion: Except in rare instances it does not mean that people are migratory, instead communities tend to occupy defined territories. Already before missionary work started in Gurakor around 1936 (talks with JOHN 1997) and when the three related clans were not at war with other tribes, they cultivated the same pieces of land. 'Shifting' refers to practices with relatively short periods of cultivation on a particular plot of land, whereby the only means people have for preserving, maintaining or restoring soil fertility is natural regeneration during long lasting fallow periods. As a rule they have not developed more defined techniques for soil conservation or improvement.

3.1 Shifting cultivation practices for subsistence and their evaluation

3.1.1 Choosing land for clearing

Primary or advanced secondary forest was rarely cleared for gardening. Instead swidden clearing was usually carried out in 15-25-year-old secondary forest regrowth. The reasons for this were manifold. First, the human effort in clearing mature rainforest by hand is considerably greater than for younger secondary regrowth especially before the introduction of steel axes. More importantly, the size, depth, and extent of roots in primary and advanced secondary forest is such that the process of clearing, even by hand, causes considerable disturbance of the soil (FREYNE, McALPINE 1987). Moreover, productivity in the resultant clearing is lower than that in cleared younger secondary growth areas (BEETS 1990, 360). Presumably, it is for this reason that

incursion into areas of advanced secondary or primary forest was invariably by slow expansion from bordering areas of existing young secondary growth rather than through new separate clearings of virgin forest. A few of the 'very strong men' sometimes did the clearing in primary forests. Today, as land becomes scarce young people have to cut new plots in virgin forest lands usually on marginal steeplands.

Garden areas were selected for clearing according to the rate of growth exhibited since the site was last abandoned and on the basis of their species composition, e.g. when weeds and cane grasses were totally shaded out. This was after fallow periods of 15-25 years. Only one or two generations ago, the prevailing cropping system still involved at least 7-8- years of fallowing, but as land became more scarce, the farmers reacted by shortening the fallow period by 3-5 years! Low bush and grassland were never used for gardens in traditional cultivation but today villagers are often forced to do so. Thus the traditional fallow system is rarely encountered today, except in some garden plots of long distance, whereby garden plots close to the settlements are frequently cultivated more often. Cultivated areas are small -generally less than one hectare- ensuring an adequate seed source from surrounding vegetation at the end of the cropping period.

Evaluation

With growing population deforestation and expansion of the shifting cultivation system into marginal steeplands is the major threat when choosing land for clearing. Additionally shortening of the fallow period and biological invasion of non-indigenous species into overexploited garden land can be very unsustainable as discussed below.

Problems of deforestation

There is general agreement that the most significant threat currently posed to PNG's biodiversity values stems from the degradation of terrestrial habitats by total or partial removal of natural forest cover. One estimate is that 200,000 hectares are cleared for subsistence gardening each year, but it is not clear what proportion of this is primary forest or what proportion represents a process of intensified cultivation (cf. FILER 1994, 187). In Gurakor local villagers are extending their practice of shifting cultivation to portions of natural forest (cf. map n°3). As most species originate in mature secondary or primary forests it is logical that forest and habitat destruction is reducing their numbers, causing a serious threat to biodiversity. As a consequence the manifold economic and socio-cultural values of such species will be eliminated or at least

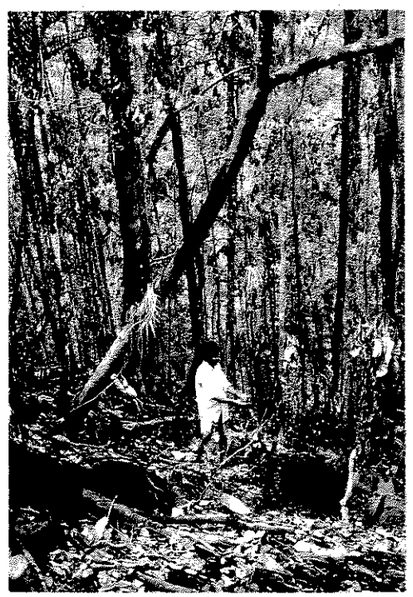

Fig. 21: Farmer in Gurakor starting with slashing in a mature secondary forest, which was damaged by uncontrolled fire during droughts, 1997.

mitigated. When marginal steeplands with slopes over 30% and very high risk to soil erosion, where most of the remaining mature forests occur, are cleared, erosion can be massive already after a short cropping period (cf. fig. 21). Soil losses to the range of 135 and 160 t/ha/yr. occur under first and second years of shifting cultivation while the same is below 5 t/ha under forest cover (RAMA, RAO 1994, 129). Deforestation further leads to degradation of ecological service functions of forests (cf. chap. 2.2.1) like mesoclimatic changes, flooding, as well as problems of water availability and quality.

Problems of shortened fallow period

Most farmers think that the duration of fallow periods can be reduced to 4 years without any other soil fertility maintenance. It is true that under traditional practices when fallow phases are long enough the soil organic matter is maintained even after many cycles of shifting cultivation and the system is one of the soundest agricultural systems (cf. BEETS 1990, 352). 10-15 year fallow cycles are sufficient in humid tropics to restore the original nitrogen status in the soil (RAMAKR. et al. 1993, 98). The nutrient retention capacity of the ecosystem in general gets drastically reduced under cultivation as a result of disturbances during the forest clearing, burning and cropping phases and much greater losses through erosion are likely for three croppings under 5-year cycles compared with one cropping under 15-year cycles. One of the main disadvantages of a 3-5 year cycle lies in the extremely reduced nitrogen capital and alarming nutrient status where soil is low in fertility (cf. ibid.) like in most parts of Gurakor's land. For these reasons the system turns into a disequilibrium through shortened fallow periods and is not sustainable anymore, that is it cannot be carried out indefinitely.

Moreover, shortening of fallow periods usually lowers diversity, which leads to reduced availability of economic and socio-cultural valuable fallow species (cf. chap. 2.2.2) and insufficient fuel wood supply.

Biological invasion- a threat to biodiversity

Greater weed infestation is a serious problem when weeds are not sufficiently shaded out in shortened fallow cycles. On deforested and degraded soil, especially on steep hillsides recovery with indigenous woody pioneers is often not possible anymore and many compositae (e.g. *Eupatorium odoratum*), *Imperata* grass and non-indigenous woody species like *Piper aduncum*, appear to be successful (cf. fig. 11). As a consequence, large pieces of land have already been invaded by those non-indigenous weeds and certainly lead to a reduction or even elimination of typical indigenous fallow species. In Gurakor, especially *Piper aduncum*[41] is an aggressive coloniser of clearings and villagers stressed that it suppresses other indigenous tree species. Though undesirable from the point of possible risks of elimination of indigenous species, *Piper aduncum* like some other non-indigenous invaders have positive effects on nutrient conservation

[41] It is native in tropical America, and is now naturalised in many tropical countries. The seeds are probably spread by birds.

in the exhausted soils. It prevents soil erosion through its rapid invasion even on steepest slopes and most degraded lands, it has medical uses, provides firewood, plus it suppresses the establishment of Imperata grassland. Although there are no studies available about this species, in general, the invasion by non-indigenous species is a real threat not only to the loss of biodiversity but also socio-economic loss of a lot of usable plants, no matter whether they just invade disturbed areas such as roadsides and land under cultivation or even natural forests.

3.1.2 Clearing practices and preparation of the garden plot

Men do the heavy clearing by hand using only steel axes and bush knives and before mission work started, only stone axes. Complete clearing of new garden plots was and still is rare in most cases. Smaller trees and underbrush are felled and the larger ones are killed usually by ring-barking so that sunlight can penetrate to the plot. At the same time selected tree species are protected and will remain or be allowed to regenerate as part of the garden. Preferred regrowth species for example, if present, are coppiced to ensure rapid reestablishment and trees that offer useful fuel-wood are ring-barked to be harvested when dry. Branches from the taller trees are cut up and stacked for fuel-wood. Other woody material is used for fencing. Subsequently, women complete the clearing by sweeping and arranging slash material for burning. Debris, such as leaves, trash of vines, branches, shrub and smaller trees, is burned usually at the end of the dry period (cf. table 4).

No tillage in the sense of turning or working the soil was and usually still is practised.

Fig. 22: Young man slashing a new garden plot on a mountain ridge far away from the settlement, Gurakor 1997.

Evaluation

Positive effects of protection, pruning, and pollarding of trees

Already during clear-felling the soil surface is disturbed as little as possible. Large trees are not felled but are pollarded and the bases burned to prevent rapid regrowth. However, the introduction of steel tools and implements has reduced the amount of labour required and allowed larger trees to be cleared. Still they are never pulled out, so that the tree stumps will provide erosion control. It is a widespread practice not to kill but to protect the trees, so that the stability of agroforested landscapes will be ensured. Even severe pruning or pollarding of valuable species such as *Hibiscus tiliaceus* or fruit trees not only opens up prospective garden sites to sunlight and provides additional organic matter or ash if gardens are burned, it also ensures renewed vigour of the regrowth and provides firewood and trellising for crops. Even ring barking, if done in a

particular way, will stimulate shooting from the base and not permanently eliminate a given tree (cf. CLARKE, THAMAN 1993, 208). Growth of protected woody species following garden abandonment, ensures speedy shade cover, which is vital for controlling grass invasions of *Imperata spp.* In addition it enriches the diversity of the fallow land with valuable tree species for food and a variety of materials. The proportion as well as the spatial arrangement of cleared land in relation to land in regrowth is such that erosion does usually not occur on a large scale.

Negative effects of recent changes

Today, some might clear the whole plot with ringbarking or subsequent removal of trees, often to allow for total tillage (e.g. for peanuts) and to maximize the production of a very few or even a single target crop (like maize or pineapple) but with short gain. This is a major factor in agro-deforestation without thinking of the consequences such as increased erosion and gradual decrease in soil fertility while before farmers would have left certain trees or parts of them because they knew the tree was beneficial to the soil and provided food and materials. If then initial grass invasions that occur immediately after abandonment of the garden are not controlled, the site may convert to an unproductive stabilized disclimax grassland.

Effects of burning on soil:

The positive effect of burning is that base cations, particularly available phosphorus, which is a limiting factor in Gurakor´s soil are added to the soil through the base saturated ashes and the tendency to growing soil acidity is balanced. Though, since slash is burned during the dry season when gales are frequent, a large amount of ash is blown away from the sites. Pools of carbon and nitrogen in the surface soil suffer substantial losses through volatilization as a result of heat released from the fire (RAMAKR. et al. 1993, 92p).

3.1.3 Planting practices

When ready for planting, such a block looks most untidy and careless. The shape of the clearing is irregular, and the 'clearing' itself a confusion of tree stumps, half burned logs, occasional standing trees, and ash (cf. fig. 23). It is sufficient, however, for the villager's purpose. Even though the plantings, that are usually done by women, are not designed according to western models, with straight rows and single crops, the distribution of crops on a garden plot is carefully planned. Value will be placed on the staple food like taro and cooking banana or cash crops like water melon or cucumber that are first planted. Yam and mami are today only rarely planted against standing saplings where very deep and fertile soil remains. Other crops like maize, clumps of

Fig. 23: Woman seeding maize in a new garden plot with banana and taro, 1997.

the gardening cycle thus providing a wider range of useful plants in the fallow period and promoting rapid tree regrowth to shade out annual weeds and grasses. Another positive effect is the diversification and stabilisation on agroforested land.

Weed and pest control

The traditional practices to basically control pests and weeds through the long fallow period until forest trees shades out annual weeds and through burning are the cheapest and most effective forms of weed and pest control. Through burning weeding is hardly necessary in the first year and pest infestation unlikely. Yet, if land is cleared and burned too often with reduced fallow cycles and longer cultivation it can become overgrown with perennial grasses like Imperata spp. This grass is recognized as an effective and rapid soil improver, but is nevertheless regarded as a plague because it demands longer and very intensive land preparation for cropping and very high weeding inputs (KOTSCHI 1990, 42, interview with McALPINE 1997). As long as a partial canopy of some trees and tall crops exists and /or the plot is relatively small the severity of luxuriant weed infestation can be reduced through shading out light-demanding weeds, grasses, and also pests problems will be mitigated since relatively easy migration of biocontrol agents from the surrounding vegetation is permitted. With the negative trend towards cropping of a limited amount and shape of plants and neglecting of crop rotation increasing incidences of pest and diseases including soil borne diseases will become hard to control contributing to an extreme decline in yields. The positive effect of traditional pest control is thus very sustainable if properly managed: Natural control aspects are maximised, and no negative effects on water, soil, air or wildlife are caused through often poisonous imported chemicals.

Fig. 25: Garden plot in Gurakor after repeated burning rapidly invaded by noxious Imperata grass, 1997.

3.1.5 Continued cropping and fallowing

The main feature of alternating cultivation was the avoidance of the common tropical problem of soil exhaustion and as shown above pest infestation by shifting of a new piece of land as soon as the yield of the existing land declines. Whereas the period of cultivation is traditionally not longer than 18 months, under land pressure today the next step in intensification is to lengthen the cropping period and still retain the shortened fallow cycle of only 3-4 years. As the harvesting of short term crops comes to an end, the garden is allowed to return to the fallow period and to be transformed into 'orchards' with plantings of tulip, breadfruit, galip, etc., so that the land continues to produce tree- and other food crops, like banana, taro and sugar cane which can

compete with the invading tall cane grasses for some years. No fallow cover is planted but, since gardeners deliberately leave tree seedlings in the ground while weeding, the plot is usually well colonized by saplings when cultivation ceases. After the garden is allowed back into the fallow stage it is rapidly invaded by weeds and short grasses which are later shaded out by woody species.

Evaluation

A problem these days is that increased frequency of fire and repeated cropping leads to soil erosion and nutrient losses thus resulting in rapid soil degradation. During the extended cropping interval, nutrient losses occur through run-off and leaching during the early rains owing to sparsely vegetal cover and soil patches exposed to erosive forces. Extending the cultivation period has another serious disadvantage, in that many stumps and seeds, from which the natural vegetation develops, are likely to be removed or die. When the land is abandoned, re-establishment of a vegetation cover is slow. The soil is then exposed to direct rainfall, erosion may become a major problem and the loss of organic matter leads to a decrease in structural stability. The nutrient losses could be improved by applying fertilizers and by controlling erosion, the costs of which are, however, beyond the means of shifting cultivators and the knowledge to do so is generally not available either.

A positive aspect is that food shortages and crop failures used to be unknown because even abandoned gardens contain considerable amounts of unharvested produce. The term 'weed' should be used with extreme caution because of the many uses gardeners have for them as medicines, fodder, mulch, roofing, fish poisons, toothbrushes, and vegetables. Amaranths, black nightshade, water spinach (*e.g. Ipomoea aquatica*) are important herbs that are sometimes even sold on markets (talks with TAE 1997). Fallow plots with woody species provide most of the materials needed for construction, building of houses and other purposes and therefore impacts on primary or advanced secondary forest are mitigated. When shortening of cropping and fallow periods are reduced, many of these benefits will be lost (cf. 2.2.2).

3.2 Special aspects of traditional farming

3.2.1 Recent agronomic techniques for maintenance of production potential

In most cases, the old cropping system is continued until the land is completely degraded, at which point a changeover to more intensive and productive alternatives is difficult. It was therefore of interest to take a closer look at some developed alternatives in traditional farming.

Integration of peanuts

Since recently, farmers have started to integrate peanuts between plantings of main food crops. This has not only had a positive effect on soil fertility as peanuts like other legumes are able to generate nitrogen but it is also a highly valuable source of protein for the inhabitants and a marketable and storable product.

Mounding

Mounding which should not be confused with composting is not common in Gurakor, but when people from the highlands or other parts of PNG married in Gurakor, they imported this traditional technique of reforming mounds or beds at each new planting. This labour intensive technique is, however, not necessary under Gurakor's freely drained soil conditions. Although it may help to increase soil productivity in the short run because fertile topsoil is accumulated to give best conditions for plantings, it will lead in the longer run just to more complete exhaustion of the soil, since no soil improving techniques are added.

Mulching, composting, and fertilization

Mulching, composting, and fertilization are still uncommon in Gurakor. Only in very few cases (old didiman) mulch, chicken manure or compost is integrated whereas in other areas of PNG, there exist traditional intensive mulching systems using special leaves for the planting of yams and taro or placing dung into the mud in irrigated taro gardens, also to aid in insect or pest control and to enhance taste (CLARKE, THAMAN 1993, 209).

3.2.2 Traditional cultivation calendar

The following local or regional calendar shows how people in Gurakor use natural climate conditions for their purposes in AF. The calendar is orientated on three different tree species, locally called Hok, Hea and Mide, that change their leaves during the year. When the leaves of one of these trees turn red or yellow, the beginning of the new season is marked. Sea-sons, however have irregularities and interruptions. Table 4 shows how these trees indicate the different seasons and what consequences it has for the shifting cultivation. People's reactions showed that the three different trees are not only understood as rational indicators for climatic conditions that influence plant growth and other processes, they are merely seen as a magico-religious symbol (cf. value of trees in brackets). It may also be for this reason that the traditional calendar has since abandonment of animist thoughts not been respected anymore and is rarely applied.

Name of tree/ season	HOK ('BAD TREE')	HEA ('GOOD TREE')	MIDE
Usually corresponding months	August to December/ January	January to February.	February to August
Colour of leafs	Yellow	Red	Orange (Red-yellow)
Indication	Algae-growth, deterioration of surface water, unfavourable growing conditions.	'good ground' favourable growing conditions, fast crop establishment	High-water and flooding, mass-movement, storms, rainy season. Sufficient food available.
Season	'Dry' season with less quantities of rain but often misty and slushy weather	Beginning of the wet season	Rainy season with heavy rains in the afternoon and night, sun during the day
Significance for agriculture	Time of slashing and burning forest	Time of planting new staple food crops	Good plant growth, time of weeding

Table 4: Traditional cultivation calendar in Gurakor

Evaluation

Positive effects

This time tested and flexible calendar is better adapted to variable climate conditions than numerous western models. The calendar helps to use natural circumstances more effectively. It is much easier to slash and burn in a quite dry forest at the end of the dry season if a mature secondary or even primary forest has to be cleared. An important feature of the system is that ground cover is maintained almost permanently, except for the short time between clearing and the development of the crops. Crops are planted at Hea, the onset of the wet season to ensure that protective ground cover is rapidly established before the heaviest rains of the mid wet season Mide. It ensures a good soil moisture regime during the initial, most critical phase of crop establishment and a rapid growth during the rainy season, Mide with sufficient quantities of rain and sunlight during the day. Of course, also weeds grow best during Mide, so that weeding often accompanied with harvesting of the first crops has to be done to eliminate rivals for light and nutrients. Therefore, the application of this calendar can help to reach maximum yields and to mitigate soil erosion. More recently introduced plants that better suit or tolerate dryer seasons (e.g. watermelon) may be planted in another sequences.

Problems

The knowledge about this useful concept and that the best yields are reached when seasonal changes are considered, stands in contradiction to farmers actions as they neither continue to use this calendar, nor do they apply any compensatory measures like watering during crop establishment. Farmers themselves answered that the disregard of the calendar frequently results in a marked decline in yields. The reason of this fact may be that although farmers seem to be aware of using the natural circumstances, they still interpret the phenomenon as supernatural powers and therefore easily abandon it with their animism. Another obstacle may be the obvious shift in seasonality throughout the last decades which makes forecasts difficult for the farmers (talks with BERGMANN 1998).

A great disadvantage of the system itself may arise when extensive use is made of the dry conditions at the end of Hok for burning forests. Especially in times of extreme droughts, e.g. during El Niño events, there is an enormous risk to cause uncontrolled bush fires. These bring about ecological and economical disasters from the local to global scale and threaten human health and life as the last El Niño event not only in PNG but also in many other countries clearly showed[42].

3.2.3 Drains and irrigation systems

In Gurakor neither ditching is necessary because soils are usually freely drained, nor is any irri-

[42] In PNG about 30-40% of the land including grassland as well as forests has been burning for weeks or even months during the 1997 El Niño event (talks with BERGMANN 1998)! Besides the burning for cultivation this fire-raising is often owing to the misunderstanding that clouds, produced through the process of burning, would bring about rain.

gation essential under normally rain-fed conditions during most of the year. Only in few cases irrigation is applied associated with traditionally taro production and today with cultivation of water cabbages. Therefore creeks are roughly dammed, the water diverted along ditches which follow the contours, and simple flood irrigation provided by breaking the wall of the ditch above the garden site, and directing it via one or more furrows into the garden. Land was usually irrigated in this way before taro was planted as well as during the growth of crops. In a neighbouring village for the same purpose water was even piped to garden sites with carefully joined bamboo pipes (CONROY, BRIDGLAND 1947, 85). Today many of these taro irrigation systems in Gurakor are not maintained anymore. Only some farmers use this method to extend naturally growing or implanted water cabbages (cf. fig.26).

Fig. 26: Irrigation system for watercress an site-stable sago palms at the edges along the ditches and creeks, Gurakor, 1997.

Evaluation

The use of ditches or even pipe systems is a marked technological advance in traditional farming to effectively use natural resources and increase productivity without much external inputs. Demanded inputs are besides good knowledge about the system regular weekly or even daily supervision and thus high labour input (interview with NIKODEM 1997), which is the major reason that it is hardly applied today. Still, it is a worthwhile investment of labour because water cabbage proved to be a good cash crop on regional markets. In the neighbouring village Patep studies by CONROY, BRIDGLAND, writing in 1947, showed the great advantage of irrigation. In unirrigated gardens 5 tons/acre taro were harvested whereas irrigated gardens yielded three times as much with 15 tons/acre. Another great advantage of such irrigation systems is the extension of the cropping period which helps to overcome seasonal food- and cash shortages during periods of drought and the better distribution of labour. As long as irrigation is applied as traditionally only on a small scale there are no major impacts on water systems or conflicts with other water uses.

3.2.4 Selection and supply of planting material or seed

Planting material of traditional tuber crops, sweet potato and perennial leafy green vegetables is usually vegetatively multiplied. Corn or other seed e.g. for water melon, peanuts, etc. are sometimes bought and then increased by the farmers them-selves.

Criteria for crop selection:

In general, farmers tend to use the following criteria for selecting their staple crops:

1. The extent to which they are familiar with a crop,
2. the agro-ecological suitability,
3. the extent to which a crop fits the farming system and the cropping pattern,
4. direct requirements of the farmers,
5. prevailing market prices and ease with which the produce can be sold;
6. relative production costs and labour demands,
7. seed supply; and possible existence of promotion schemes for the crop in question.

Which criteria are given more weight depends on the degree of commercialization. In most cases, the farmer's familiarity with the crop and regional marketability will count most whereas the last factor (7) is today only of that significance that government or other promotion schemes hardly exist.

Incorporation of introduced species

Many post-European-contact introductions, including food plants, timber trees, and ornamentals have been tested, selected, and incorporated into today's systems to such an extent that the status of many species remains unclear as to whether they are local domestic or indigenous plants, aboriginal introductions or early post-European-contact introductions (cf. CLARKE,THAMAN 1993,195)[43]. Plant introductions in the colonial time were slow to spread and became important foods only in the 1960s. They included Chinese taro, cassava, pumpkin, beans and peanuts. Maize, in contrast, spread quickly to areas well beyond the colonial frontier, probably because it fitted well into existing mixed garden patterns (cf. ALLEN 1992, 55). Chocko a widely used leafy green vegetable and fruit appeared to become one of the most important vegetables in many areas.

Evaluation

Advantages of traditional crop selection

As people in Gurakor tend to grow time tested crops which are highly suitable to their environment (root crops, leafy green vegetables, etc.), naturally well-adapted to prevailing agro-climatic conditions, and because they do usually not attempt to grow 'exotic' or recently imported crops, the risk of harvest losses is relatively low. High external inputs and scientific husbandry are not necessary as with imported high-yielding varieties. Other positive aspects of a great variety of local cultivars is the greater stability and great potential of biogenetic resources. For their long-

[43] Of the 419 agroforestry plants, approximately 172 (41%) are probably indigenous to most Pacific islands where they are found; 13 are probably aboriginal introductions; 40 either indigenous or aboriginal introductions; 147 (35%) are recent post-European-contact introductions; 47 are indigenous, recent or /and aboriginal introductions depending on the area (cf. CLARKE, THAMAN 1993, 196). It is extremely difficult to determine whether some species were indigenous or introduced by early settlers, and their status may be different in different areas.

term positive effects traditional crop selection is highly sustainable.

Problems with present crop selection

The problem is that most people today prefer fast growing crops and a selected range of staples and marketable food, particularly sweet potato. Therefore the manifold positive effects of multi-storey planting schemes remain unused. Moreover monocultures of annual crops tend to be detrimental to the environment and great caution has to be exercised.

It is mainly in the sphere of arts and crafts, ceremonial performance and therapeutic practices that formerly cultivated or other useful species have been seriously and simultaneously eroded. Owing to soil fertility, high labour costs, bitter taste and other reasons there has also been a substantial reduction in the range of traditional food species which were formerly valued for feasts, traditions or for their important properties such as non–perishability (esp.yam). The diversity, required to meet the basic needs of the population, is enormous but, upon contact with the outside world and soon after commencement of trade, it declined as villagers came to rely on foreign products which they often cannot afford. The move from peasants producing with their own resources a wide variety of AF products to specialized production of only a few crops for the market is and certainly will be the most important threat of biodiversity for cultivated lands.

Problems with promotion of planting material and seeds

Negative effects may arise through vegetative crop multiplication which often leads to the expansion of viruses and other diseases especially in taro, yam and aibika which can seriously threaten traditional varieties (talks with PETT 1997) and biodiversity. Another problem arises when in-vitro propagated hybrid seeds are bought and later propagated by the farmers themselves. Then a rapid decline in yields is common if hybrid seed is not constantly bought.

Positive aspects of introduced species and cultivars

Often introduced cultigenes which have become naturalized are regarded as having significant cultural or ecological value, like the aboriginally introduced social and economically important betel-nut palm and betel pepper, the introduced dye annatto and a wide range of other introduced plants for construction, fibre, perfumes, decorations, for medical, magic or other purposes (cf. app. 3). Post-European-contact introductions include important long-established food trees such as the papaya, mango, avocado, a range of citrus species, guava, soursop and banana clones, the ubiquitous perennial chilli pepper, etc. Many new, often high-yielding, cultivars or clones of plants such as the coconut palm, bananas, and citrus trees as well as other recent introductions including tea, coffee, oil-palm, rubber, cocoa, the common bamboo, cotton, kapok and a number of fast-growing multi-purpose trees are of commercial importance (cf. app.3 H, K).

Problems with escapees from cultivation

Although many of these species cannot be considered fully naturalized as they often grow on disturbed sites and under cultivation only (CLARKE, THAMANN 1993, 197pp), it has to be examined whether they could become major weeds even when restricted to disturbed lands.

Despite the relative stringency of national quarantine regulations today, there are several well-known examples of the deliberate or accidental introduction of non-indigenous organisms which attack native species. Little is known about the overall range and impact of such alien intrusions in PNG but it is obvious that some cultivars that were introduced by colonial powers as beneficial plants have become noxious weeds threatening indigenous biodiversity. Particularly introduced leguminous species with beneficial effect on soil fertility in AF like *Leucaena leucocephala*[44], Lantana or various mimosa species are already declared as serious weeds in many tropical countries at least in seminatural habitats (cf. CRONK, FULLER 1995), whereas they have not yet been recorded as invading undisturbed forests in PNG. Even introduced widely established fruits like Guava trees or a wild passion fruit from South America (*Passiflora foetida*) have become noxious weeds in PNG (ibid., 187; HENTY, PRITCHARD 1988, 136).

3.2.5 Traditional and recent animal husbandry

Traditional livestock was limited to pigs. Sows were, and in many other areas of PNG still are, raised extensively and are allowed to roam village compounds and fallow garden areas. Pigs are seldom intensively looked after. When they are not fed they just go out by themselves to find food. Today there are no domesticated pigs anymore, only about three wild pigs are kept in the whole area of Gurakor. Few families keep some chickens and one of them quite intensively broilers as contract farmer with a chicken farm in a neighbouring village, Zenag. He gets all food inputs from them and provides work and the chicken house which is made of bush material and wire. One case was reported where a farmer has cleared a piece of land and sown it as pasture for cattle, but even this single attempt in cattle farming failed after the death of the farmer. Thus there are only very few livestock in Gurakor. Still there are some efforts to raise wild animals, like young cassowaries or possums domestically but not to breed them in captivity.

Evaluation

As pigs are traditionally not kept in captivity they often cause considerable damage to food gardens and soil. This was the reason for Gurakor's clans to totally abandon pigs as conflicts between the three different clans increased, when in times of peace they did not have to fence off their gardens against human enemies anymore. Special stocks and primitive land-races of pigs, the most important livestock in PNG, are therefore already lost in Gurakor. The traditional way in PNG of keeping pigs may only need very low labour inputs and provide beneficial effects like clearing away wastes and low quality food under and around the houses, storage of food, serving numerous payments, e.g. as dowry, and as a sign of wealth. As long as pigs are only consumed during feasts or special events in PNG, they make little or no contribution to a family's nutritional well-being. Like introduced plant invaders escaped pigs and other domesticated animals

[44] The risk of *Leucaena* becoming a weed is minimised in areas where human demand for its products is high and because of their reduced seed production except for *L. diversifolia* (cf. JONES, SHELTON 1994, 19).

(esp. dogs and cats aside from unintentional rats) consume native species and disturb their natural or seminatural habitats if they are not kept in captivity or other control. In this context the Giant African Snail (*Achatina fulica*) that was introduced as food should be mentioned. It is a widespread pest in gardens (cf. GRESSITT 1982, 160) and neither eaten by villagers nor fed to pigs.

Manure is nowhere used in cropping to add nutrients to the soil and keeping chickens is often connected with high external inputs. Keeping livestock is therefore truly underexploited and/or not effectively integrated into the AFS.

A promising but relatively unknown alternative might be the raising of wild animals in captivity as they are well adapted to the system and provide an alternative source of meat.

3.2.6 Problems of harvest losses, storage and processing

Post harvest losses in Gurakor are often considerable. For example small tubers or cobs of maize are deliberately left on the plot, because there is no point for a family to carry the heavy load back to the village since there is no livestock to feed it to. Neither is it worthwhile to walk the long way back some days or weeks later to harvest a small proportion that would mature little later. Indeed long distances or labour shortages often lead to inefficiency, lacking control and thus harvest losses. Fruits are often neglected and already spoil in the fields although they would provide useful micro-nutrients. Post-harvest operations such as processing, storing and transporting are neglected or unknown leading to high harvest losses. Insufficient processing, storing equipment and lacking husbandry such as pigs that could efficiently 'store' low quality food is another reason that substantial proportions of agricultural produce are wasted and that the system becomes vulnerable to seasonal or periodical food shortages.

3.3 Cash cropping

3.3.1 Coffee production

In Gurakor coffee rather than cocoa is the usual cash crop, and *Leucaena leucocephala* instead of coconut is the overstory species (cf. fig.27). Coffee has widely been adopted in the region and also in Gurakor there are four relatively small permanent coffee plantations (cf. map n°3). The permanent rows of coffee trees are interplanted with *Leucaena spp.* as shade trees and

Fig. 27: Path through coffee plantation on Nembengmun since 1954, interplanted with Leucaena leucocephala and few bananas, 1997.

sometimes underplanted with shade-tolerant food crops such as bananas or taro in the initial stage or after the trees are coppiced. There are no outside inputs such as fertilizers or pesticides.

Evaluation

Sustained production is maintained only through litterfall, mulch of coppiced trees and slashed weeds, and through nitrogen fixation of *Leucaena spp.* Shade trees mitigate weed infestation, regulate moisture regime, control erosion and through the relatively small size of coffee plots and intercroppings pest infestations are naturally regulated. Such agroforestry systems are a feature of high self regulation and are therefore very sustainable from an ecological but also economic point of view since no external inputs are necessary to maintain production. Therefore, the risk of capital loss is not too high when coffee prices drastically drop or input prices rise.

The problem is that smallholders are weak in husbandry. Weeding and clearing are inadequately performed, mulching is neglected so that most of the blocks are underexploited, Reasons are probably the lack of advice through extension services and of incentives for higher production. Declining coffee prices and steadily worsened terms-of trade make the high labour costs for good maintenance, harvesting and processing of coffee not worthwhile for farmers and thus contribute to the fact that it is normally simply not done. Therefore often fertile pieces of land are just wasted since no food or other useful crops are interplanted.

3.3.2 Other cash cropping

Often the cash crop sold on local markets is the same as the subsistence crop (e.g. sweet potato, maize, root crops, peanuts, betel-nuts) and the surplus production constitutes the cash crop. Some other crops are only produced for cash (like water cabbage or bitter gourd) and are seldom eaten by villagers in Gurakor. In other cases the home consumption of high valued fruits or nuts such as pineapples, water melon, galip-nuts, etc. is desisted from as they are planted to gain cash.

Evaluation

The production of such regionally sold cash crops is economically much more stable than export crops because prices are not so seriously attacked as on international markets and there is a constant and even growing need for most of these crops in nearby centres. The ecological sustainability is the same as in the traditional system with its recent changes explained above.

A problem that arises in any form of cash cropping in Gurakor is that often the best agricultural land, as well as the main agricultural activities, are devoted to these cash crops and self-sufficiency is neglected. Other problems concerning regional cash cropping are merely a problem of marketing which has already been explained in chap. 2.3.7.

3.4 Hunting, fishing and gathering

Agriculture is a major source of food, but the forest also provides a significant input to the food intake and for different materials of the people in Gurakor. Wildlife is still extensively used and

some men recorded to go hunting up to three times or more during a week. Still, fishing, hunting and harvesting of wild food are secondary activities and in most cases irregularly practised despite being close to the forest and rivers or creeks. Animals including wild pigs, possums, cuscuses, tree kangaroos, bandicoots, flying foxes, wild-fowl and many other birds as well as their eggs are eaten, the bird feathers or furs (mammal pelts for strings) used to be and sometimes still are applied for body ornamentation in traditional dances. In some cases snakes and monitor lizards are eaten but mainly their skins are used for traditional hand drums (kundus).

Men use a variety of traps, go hunting with their hunting dogs, follow game with bow and arrow and bows or just catch them by hand. Towards the end of the colonial period, shotgun licences were issued to rural villagers and they were extensively used for hunting. However today, hunting with guns instead of traditional weapons has been eradicated since the government has confiscated them. Fish, eels and prawns in the creeks and little ponds at the bottom of water falls are also caught by women using different ways of fishing: Either locals dig poisonous ropes, which are deliberately grown close to the creeks, grind them with stones, and put them into the water so that all the fish will die, they build a small dam to catch the fish or they just shoot them with a knife or spear. Since Europeans introduced hooks, fish is also caught with those.

Fig. 28: Boys with hunted possum and prawns in Gurakor' s forest, 1997.

Many wild fruits, leaves and root crops, extracts, timber, bark or ropes are gathered for their food, for handicraft, tools and weapons, for medical and many other purposes as comprehensively explained in chap. 2.2.1. and 2.2.6.

Evaluation

There are no customary hunting restrictions in the area like restricting access for hunting at particular times. Still, traditionally villagers would only hunt sufficient wildlife for the family's needs and if they went to a special place on one day, they would go to another place in the following days and come back only after a certain time. Fish poisoning is actually tabooed today because villagers themselves recognized the unsustainability and inequity of this practice, but some still practice it. The extractivism and gathering of wild plant materials is only for subsistence and at the moment does not seem to endanger ecological stability. In some places bans or taboos are limiting hunting, harvesting from plants or other resources (cf. chap. 2.3.5). Due to the reduction of shotgun use, the local wildlife may not suffer either, if people are now more carefree.

It seems that the society maintains a balance with forest and other wildlife resources and that it has developed at least some conservational practices that regulate its pattern of resource usage, but as there are no data on plant or animal abundance in the area it is not possible to say whether hunting and harvesting is still on a sustainable level. Overexploitation of wildlife is likely since there is hardly any animal husbandry in Gurakor to meet rising protein demands of the growing population. Main threats to national biodiversity values are not so easily subjected to a single standard of measurement, even if more data had been available to indicate the extent of each one. Rural villagers are probably guilty of exploiting some species in ways which are unsustainable in their own right and have negative side-effects on other species within specific habitats (like poisoning). Some of these activities are confined to the subsistence sector while others are primarily oriented towards the global trade in rare species especially Birds of Paradise, that are now endangered and protected (cf. FILER 1994, 187; GRESSITT 1982, 162).

4 STRENGTHS AND WEAKNESSES OF LOCAL CIRCUMSTANCES AND PRESENT AGROFORESTRY PRACTICES

In this chapter most important strengths and weaknesses of natural, socio-economic and cultural circumstances and,in conjunction with those,of the AF practices are reviewed and summarized.

LOCAL CIRCUMSTANCES FOR AGROFORESTRY		
	Strengths	**Weaknesses**
concerning natural resources	• On slightly undulating alluvial mudflow fans relatively fertile and robust land, suitable for cultivation under good management. • Rainfed and warm climate conditions allow planting and harvesting throughout most of the year, if well managed. • Intact water systems with sufficient and clean water. • Enormous variety of biological resources in natural, semi-natural and cultivated habitats for almost all aspects of life. • Large quantities of relatively undisturbed virgin or mature secondary rainforests on the mountains with manifold economic, socio-cultural and ecological benefits.	• Restricted land that is suitable for cultivation, extension into marginal lands only with severe limitations and destruction. • High vulnerability of soil towards degradation and leaching. • Irregular climatic perturbation can be disastrous and seasonal changes can cause crop, labour and economic deficiencies. • Some invasive species, pests and weeds threaten biodiversity and farmer economy. • High vulnerability of forest biodiversity to destruction and misuse due to low abundance and restricted regenerability on marginal land.
concerning human resources and socio-economic circumstances	• Social security, self-help and cohesion within clans and families. • Land ownership allows self-sufficiency for all families and individual property of crops. • Democratic, peaceful and generally achievement-orientated society. • Traditional self-reliance and sufficiency in many aspects of live (e.g. health care). • Wide traditional knowledge about natural resource base, esp. useful species, natural phenomena, and knowledge and skills for appropriate forms of their use. • Critical attitude towards and careful testing of innovations. • Good road access to urban centres, markets. • HDC as constant buyer of food products and provider of periodical jobs. • Vicinity and cooperation with HDC staff, use of its facilities e.g. for seminars. • Possibility for training at ATS.	• Inter-clan rivalities and inefficiency through nepotism ('Wantok system'). • Insufficient access to resources under land pressure for women or land-less people. • Population growth causes pressure on land. • Labour shortages through drift to urban centres, unwillingness to work or social duties. • Decreasing self-reliance and self-sufficiency. • Abandonment of traditional knowledge and skills in sustainable resource use. • Malnutrition for people's own fault, and burden of tropical diseases. • Lack of experience and knowledge to meet changed circumstances. • Unrealistic viewpoints or resignation. • Insufficient/inefficient/inappropriate education, extension-and health service, marketing, cooperatives, processing etc. • Insufficient income-generating activities for young people and drop-outs and criminality. • Low and unstable cash incomes. • Increasing competition on world market.

AGROFORESTRY PRACTICES AND LAND USES		
	Strengths	**Weaknesses**
Economic attributes	• Generally high productivity per labour input and very high output per energy input. • Principally high degree of self regulation, economic stability through diversity, flexibility and adaptability of the system. • Entire subsistence for most simple needs, no cash intensive external inputs, independence of subsidies. • Preference of more stable regional market production for national food security. • Flexible labour timing except for people that are involved in coffee picking. • Diversity provides high potential of timber and non-timber products. • Small scale irrigation for better productivity and division of labour and cash income	• Low productivity per land unit and increasing labour/ time input due to soil degradation and longer distances. • Little and irregular surplus production, no consistent cash income and no financial savings available for investments. • Trend towards reduction of traditional species. • Overemphasis on marketing before food subsistence. • Increasing dependency on imported food/meat.. • Incapability of traditional practices towards changed circumstances (land pressure etc.) • Peak harvest and post harvest losses, insufficient storing/ processing. • Lacking or inefficient integration of livestock.
Ecological attributes	As long as enough land is available very sound and stable system with high biodiversity: • A virtually closed system with hardly any external inputs. • Only renewable resources as inputs. • Beneficial effects through fallow process for production capacity of soil, run-off and erosion control, biodiversity, weed/pest management and meso-climatic equilibrium. • Protection of beneficial species, esp. trees. • High diversity ensures self-regulation, erosion control, efficient use of resources, stability and conservation of biodiversity. • Burning kills pests and weeds and balances base saturation. • Minimum disturbance of soil. • Soil improvement through few legumes such as peanuts and Leucaena. • No pollution of environment or disturbance of habitats through application of agricultural chemicals.	As land becomes limiting system becomes disastrous environmentally and ineffective: • Increasing imbalance and inefficiency through higher nutrient export than import • Shortening of fallow period and extension of cropping period with repeated burning leads to soil degradation, erosion, inequilibrium of climate and moisture conditions, invasion of weeds/ non-indigenous plants and reduction of biodiversity. • High risk of uncontrolled fire, impacts on local by global climate. • Extension into marginal lands leads to rapid soil erosion and degradation, destruction of forests with manifold benefits and functions. • Reduced use/planting of traditionally valuable species leads to massive loss of biodiversity. • Only occasional replanting of trees and limited use of leguminous plants. • Inefficient use of waste and by-products. • Unrealized or neglected promotion and tapping of the great array of biological resources. • Destruction through wild pigs or hunting dogs.

	Strengths	Weaknesses
Socio-cultural attributes	• In general provides great variety of healthy traditional food and medicines. • High equability because all methods and material, crops, energy applied in the FS are available for all peasant farmers. • In general appropriate to traditional lifestyle. • Provides socio-culturally important raw materials, decorations or stimulants. • Is sometimes subject to mythology and conserves secret meeting sites or other valued components of the landscape.	• Health problems with decreasing food diversity and production of protein/ medicine. • Heavy loads on increasingly long ways to fields esp. for women and sexdiscrimination in general. • Erosion of culture with commercialization, misinterpretation or mismanagement (e.g. abandonment of pigs!) • Insufficient satisfaction for changed needs. • Decreasing political acceptability because of low cash flow, environmental deterioration and decreasing well-being of community.

Table 5: Summary of strengths and weaknesses of local circumstances and present agroforestry practices.

Systems of shifting cultivation have long been characterized as 'primitive' and 'resource-depleting' and it is common to hear arguments that these primitive forms of land use should be replaced by permanent cultivation, the use of fertilizers and high-yielding introduced plant varieties. However, there is good evidence that traditional AF practices with shifting cultivation are conservative and have maintained AF productivity over millennia in PNG (cf. YEN, MUMMERY 1990). This analysis of strengths as well as recent interest in AF and sustainable systems of agriculture is giving support to arguments that many forms of shifting cultivation are viable systems of land use and are critically important in the context of increasing dependence of high inputs in modern agricultural systems (cf. CLARKE, THAMAN 1993; ALLEN 1989). On the other hand there is sound evidence that there have been past episodes of degradation in many aspects associated with increasing population, changed needs, customs and interference by man. As the system is vulnerable to changes, especially those which bring about a shortening of the fallow period, the originally very self-sufficient and stable system moves into disequilibrium and the system in Gurakor is no longer viable in its present form. Still many components of the system remain very sustainable in itself and are therefore an important basis for any improvement or change.

5 SUSTAINABLE AND APPRORIATE DEVELOPMENT CONCEPT

5.1 Developing an appropriate and sustainable agroforestry system

5.1.1 Think globally- act locally

As examined above the economic and socio-cultural basis of Gurakor is the AFS with shifting cultivation. To sustain this basis also for future generations and to 'think globally', the national and international aims and strategies analysed in the introductory part of this thesis, have to be the principles of a development concept of improved AF development in Gurakor. These selected general aims and strategies fit well into the local system and are therefore just repeated in table 6 to keep them in mind as a basis for the development of more detailed inventions and measures. As comprehensively explained above the present system of shifting cultivation in Gurakor is vulnerable to changes such as shortening of the fallow period and is therefore unsustainable in its present form. In this chapter an attempt was made to design a development concept with a number of interventions for the special conditions and problems in the village Gurakor. These interventions should be considered in any attempt from outside to change, to improve or to develop the system in Gurakor – to 'act locally'.

Practical interventions include the strengths of the traditional shifting cultivation system that are already available and add innovations supplemented by experiences of improved and more permanent farming in PNG and knowledge of modern research in AF to meet the weaknesses described above. The term 'intervention' was used to indicate that means and ways to improve the system within the village need stimulation or incentives from outside because local knowledge and experience to meet future trends is limited or sustainable traditional methods might get lost if their high value is not fully understood. An inventory was made with interventions that concentrate on farming practices, land use and processing on a local level. The final package of interventions, or of an alternative system as a whole, must be developed and tested together with the shifting cultivators in Gurakor and is part of the implementation.

In a separate section, instruments are selected for the implementation of interventions. They are part of the fulfilment of socio-economic aspects of sustainable development and are merely forms of human capacity building, promotion of self-reliance and participation besides improvements in marketing.

5.1.2 Major challenges for interventions

Aside from the aims and strategies of table 6 that must be fulfilled, it is just pointed out that the general aim is to develop sustainable AF and not just agriculture. This means to couple food, fuelwood, material, medicine and meat production efforts with those that enhance environmental quality. As shown in chap.2 most productive lands are already farmed and from an ecological, economic and socio-cultural point of view (distances, steep lands) further clearing of forests on steep slopes, far away from the settlement for crop production is unsustainable. Therefore

SUSTAINABLE AGROFORESTRY FOR SUBSISTENCE FARMERS IN GURAKOR		
	Aims	**Strategies**
Ecological criteria	• Preserve, increase or restore productivity of land in areas under cultivation [a] and soil functions of regulation [a] • Control degradation, erosion and mass movement [a] • Safeguard groundwater and surface water quality and quantity [a+d+i] • Protect biodiversity and sustainable use of biological resources and their components [a+b+d+n+p] • Maintain equilibrium of climate and promote non-generative resources [a+c fao]	• Promote integrated (appropriate alternative [o]) farming practices (integrated fertilization and pest management) [a] • Improve management of inputs [a] through effective use of local resources (soil, water, wastes, genetic resources, AF) [a+n] • Diversify cropping and production systems [a] • Develop methods to control runoff, evaporation [a+o], soil erosion, mass movement, degradation [a] and safeguard water purification [o] • Sustainably manage and protect forests, their resources and functions [a+f] esp. in mountainous and water catchment areas [a] • Avoid introduction of and/or control non-indigenous species [a+b] • Promote and tap a greater array of indigenous plant and animal genetic recourses instead, like well adapted traditional species/varieties in agriculture [a+b] • Promote renewable energy and other resources (wood/ biogas)[a+n+f] Recognize, enhance and promote AF [a+ f+n]
Economic criteria	• Satisfy basic material needs (quality and quantity of food, drinking water, firewood, medicine, materials, etc.) [a+d+n] • Promote better self-sufficiency/ self reliance [a+n+p] • Ensure economic stability and resilience of the system [a+d] • Offer opportunities for economic development and eradicate poverty [a+c+n]	• Intensify and diversify farming systems (AF) [a] • Use site stable technologies and crops [o] • Promote efficient use of indigenous resources (knowledge!) and low input technologies, and minimize external inputs [a] • Support small scale systems for subsistence market [n] • Enhance subsistence production, and possibilities for small scale business and surplus production [a+n] • Improve and promote storing and marketing infrastructure [a] • Develop adaptable and diversified structures [a] • Balance seasonal labour-peaks [o] • Promote equal and appropriate education [n]
Socio-cultural criteria	• Human beings as the centre of sustainable development [b+d+o] • Promote and develop human resources [a+n] • Promote social justice and intergenerational and intragenerational equity [a+d+n+p] • Ensure healthy life in intact environment [a+d+c] (clean drinking water [a+n], sufficient and healthy food [a+fao], basic medical care [a]) • Satisfy immaterial basic needs and a productive life[o+d] (higher level social and cultural necessities and contentment [o])	• Promote participation, cooperation and information and better linkages of all affected people [a+n] • Strengthen/ participate underprivileged groups [a+n] • Tap and promote traditional knowledge [a+n] • Ensure equal possibilities for education and training [a-n] • Maintain or promote self-reliance [a+n+p] • Integrate sustainable/ appropriate technologies in AF [a] • Ensure fair access to different resources (land, finances, inputs, markets) [n+ a] • Built on and safeguard local/ PNG's social, cultural, spiritual, and physical resources, and emphasize moral and spiritual duties to conservation = 'PNG ways' [a+n+p] • Serve contentment of personal situation , ensure social contacts, safeguard independent and self-guarded lifestyle a and other immaterial needs [o].

Table. 6: Aims and strategies for sustainable and appropriate agroforestry in Gurakor (cf. [a] Agenda 21, [b] CBD, [c] CCC, [d] RDED, [f] FP, [i] YATSU, [n] NSDS, [p] CPNG-P, [o] own interpretation).

production must primarily come from increases in yields per hectare without any undesirable (long-term) side effects. The second major challenge is to share low income people in the benefits of new technologies so that innovations must be most cost-effective in their application and feasible to adoption. This means that use of 'Western' development routes that often overstress reduction of labour through high inputs of energy, capital and management would be inappropriate and unsustainable in many aspects. Further interventions or measures should least interfere with peoples' culture and values and great attention must be paid whether the proposed solutions are likely to be socially adapted by the farming families.

5.1.3 Interventions in time and space, combined to different forms of agroforestry systems

Surely the farmers might not be able or willing to adopt all of the interventions described in the following chapter at once. Still, they should try and integrate as many measures as possible to avoid further land degradation.

Short and long term interventions

Reflecting the urgency of problems, social requirements and economic constraints like the adaptability and readiness of farmers, the measures are divided into two different categories/priorities for the short term and for the longer term (cf. table 7):

Measures that are most urgent and viable in the *short run* only require very few investments to start the measure or no external inputs at all. They do not interfere with the local culture/customs but are merely based on local knowledge, so that they do not require higher education. Most appropriate and successful ways, for example, to raise productivity in the short-run are simple improvements in crop husbandry or physical steps.

Measures that might be necessary for the *long term* demand better explanation and training. If possibilities through locally available resources are exhausted, the integration of external inputs (like livestock, better handtools or organic and mineral fertilizers) might be necessary in the long run. Of course, these long term interventions could partly or on the whole also be applied in the short run, if enough incentives are available.

Combining interventions to improved agroforestry systems

Interventions, that are discussed in isolation below, are part of a whole system and interfere with each other in many ways so that they cannot be used in isolation. The bundle of short term interventions therefore can be seen as an *improved shifting cultivation* system with more effective use of biological processes like mulching, use of legumes and permanent crops and diversification. The bundle of 'long term measures' especially include a livestock component into the AFS and advanced technologies in crop husbandry and erosion control. Thereby the repeated use of waste products can minimize the cost of investment and increase production. Such diversified systems are also called *'Mixed Farming System' or 'Agrisilvopastoral system'*.

According to land availability, soil conditions and slope, distance to settlements and population growth, there can and must be a gradual change in agroforestry systems from the present shifting cultivation system with already shortened fallow periods

- over **controlled shifting cultivation** with regulated or planted fallow
  a. tree and shrub fallow and arable crop sequence or
  b. leguminous fallow and arable crop sequence with down to 3 or even 1 year duration,
- **permanent agroforestry** with tree, shrub and arable crop combinations, alley cropping and tree crop plantations, toward
- **mixed farming** with integration of livestock production.

When talking about such changes it has to be stressed that most of the soil types are unsuitable for continuous cultivation unless the sites are carefully selected, cleared, and prepared, and unless the new agricultural system can maintain soil fertility. This requires levels of management which are generally underestimated by policy-makers.

Arrangement of different systems in space

Already in the short term, more permanent mixed farming systems might be appropriate because permanent *homegardens* in the close vicinity of homesteads can best ensure a constant supply of staple food, vegetables, fruits, fodder and meat and therefore a balanced nutrition. They additionally provide firewood and medicine for the family and contribute to a more effective nutrient cycling and higher productivity through better use of wastes, better control and husbandry on the garden plot assured through the shortened distance.

Fields with longer distances to the village may include controlled or intensified forms of fallow cycles. They are appropriate for the production of marketable food, particularly useful tree species for cash cropping, different raw materials, medicine and firewood (or charcoal production).

To do justice to the different land capability classes (cf. map n°2), land with good flexibility (class A) can quite intensively be used with larger quantities of annual crops in combination with good crop husbandry and plant nutrition, whereas land with moderate and low flexibility (class B+C) additionally needs special attention of physical measurements to prevent soil erosion. On such marginal land controlled shifting cultivation may even in the long term be the best management practice to restore the production capacity of the soil (cf. 5.3.4). With increasing slope the proportion of trees should be raised, and above 30%, land should not be cultivated with annual crops at all. If land was already cultivated, the best possibilities for sustainable use of these marginal steep lands are permanent polycultural orchards or sustainable use of wild food and other forests resources. Likewise along creeks and rivers, particularly where they are deeply dissected or subject to flooding, permanent, dense canopy and ground covers are necessary if protection against erosion and impacts on water systems shall be achieved.

It is also important to grow more trees along the streets footpaths so that women and also men who come from the fields can walk in the shade while carrying their heavy loads.

There is no definite scope of sustainable AF, how many activities should be fitted in the farm. It should be a versatile system suitable for any kind of social, economic and physical or biological environment of a farming household and it can be small as half a hectare per family or larger for more commercial farming. The concept for sustainable AF must predominately be understood as a stepwise improvement rather than a total transformation of land use.

5.1.4 The need for improved agroforestry as an intervention

Almost all of the objectives for a sustainable land use system for subsistence can be furthered, either directly or indirectly through production and service functions of agroforestry which often intertwine. Through the promotion of properly managed and designed polycultural AFSs with deliberate integration of trees the following advantages can be reached according to CLARKE, THAMAN (1993, 31p); BEETS (1990, 487pp) and NAIR (1989, 568pp):

Ecological benefits

- AF can increase *land productivity* particularly when compatible and desirable woody perennials are included (cf.fig. 29). Several possible mechanisms are:
- marked improvements in the physical conditions of the soil in permeability, water-holding capacity, aggregate stability, and soil temperature regimes through inclusion of trees and woody perennials in the long run and therefore a *better soil medium* for plant growth,
- better soil cover and thereby *reduced erosion, surface run-off and siltation* of down- stream aquatic ecosystems, less *leaching of nutrients*, through multi-layer crop canopies and trees as most important components for the protection of soil and water systems on farmlands that are prone to erosion hazards
- *favourable influence* of trees on *hydrological characteristics* from the micro-site to the farm and regional levels[45] through lowering of soil surface temperature, reduction of evaporation of soil moisture and run-off control.
- more efficient *recycling of nutrients* by deep-rooted trees, that pump up nutrients,
- addition of leaf litter and other plant parts *increase organic-matter* content of the soil,
- which again can result in *a moderating effect* on extreme soil reactions like in Tropudalfs, in *increased activity* of the favourable *micro-organisms* in the root zone and biological de-nitrogen fixation or solving of relatively unavailable nutrients like phosphate (e.g. through the activity of mycorrhizae and phosphate-solving bacteria),
- *commensalistic* effects through micro-organisms like growth-promoting substances through desirable interaction and cause on the growth of plant species,
- *complementary interactions* between interplanted species and more efficient utilization of

[45] Although the effect of water use by a tree component on water availability to crop plants in different climatic conditions is not yet fully understood, there is evidence that the hydrological characteristics of catchment areas are favourably influenced by the presence of trees. Fast growing trees, however, may put a heavy demand on soil moisture, and unless properly managed, this can lead to adverse effects in drier seasons (cf. NAIR 1989).

nutrients because of different nutrient-absorbing root zones and improved nutrient release or availability,

- *better adaption* and *decrease of instability* associated with environmental deterioration because AFSs resemble natural eco-systems, they shade out grasses or other weeds and reduce pest problems through their diversity of crops.
- *AF reduces pressure on forests*, and therefore maintains of their manifold benefits.
- *It makes better use of the unexplored* potential of a large number of locally available trees and agricultural crops and therefore conserves genetic resources.

The magnitude of the environmental benefits depends on the proportion of trees in the system: the more trees the greater the long term benefits, often, however, the short term productivity of annual crops then decreases. Thus a series of combinations of annual and tree crops, ranging from almost pure agriculture at one end to almost pure forestry, at the other is possible (BEETS 1990, 489).

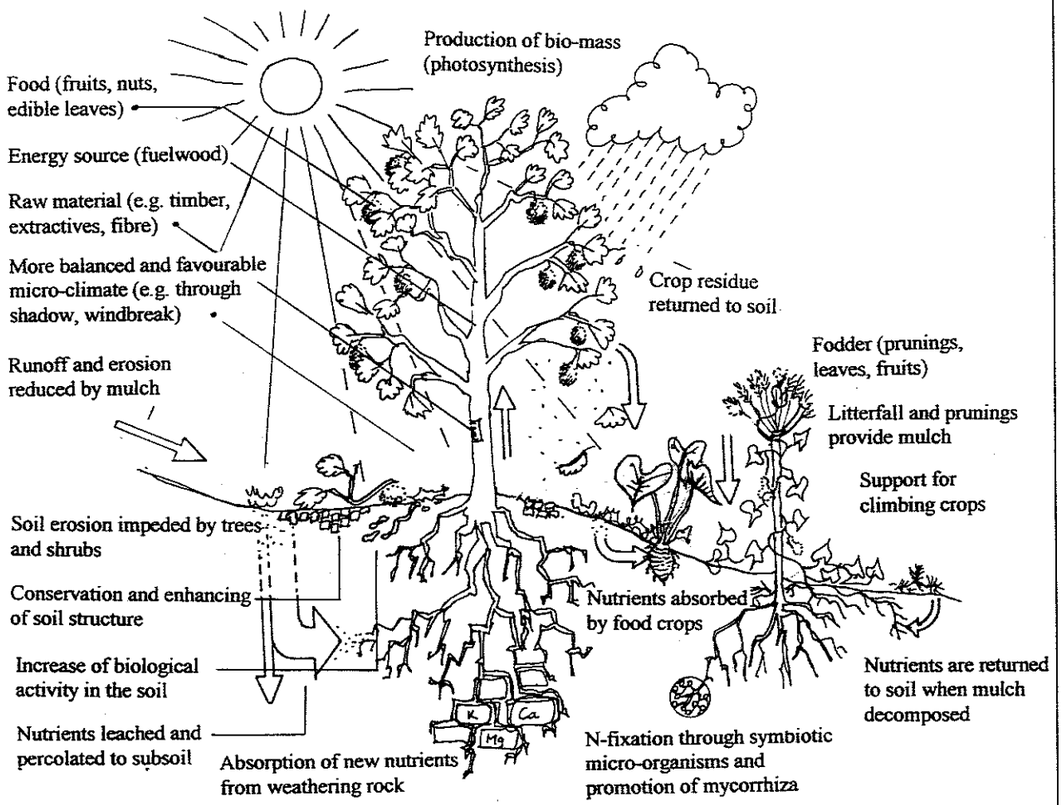

Fig. 29: Trees as multifunctional components of the agroforestry system

Economic importance:

- AF could have the positive effect in *reversing dependency on imports* and on ever-increasing foreign exchange problems.
- It *reduces the incidence* of total crop failure (if one crop fails others might succeed).
- It increases the total amount of food produced, and improves the regularity of supply
- An improvement of AF would also increase returns on under-utilized natural and cultural resources and increase *long-term productivity*.
- It could also lead to improved use of scarce capital and aid and could minimize public expenditure through the maximization of *self-help* on the part of the communities involved.
- It *provides manifold products* esp. through multi-purpose trees or palms, legumes, cash crops, etc. to meet the basic needs such as medicines, fruit, fodder, fuel and construction wood, and other products that can increase farm incomes and self sufficiency.

Social benefits

- Given access to land, polycultural plantings are technically *within means of even the poorest* families since inexpensive readily available, time-tested, local technologies, the huge variety of plants and cultural practices are already available.
- As all households can benefit from improved AF, its systematic promotion could bring about more *equitable* and balanced development, local *participation* and *involvement of women* in AF–development and provide new employment also for men.
- Improved AF can contribute to the *quality of life* (improving nutrition and health due to increased quantities of food stuffs, improved quality and greater choice), better *standards of rural living* from increased employment opportunities, higher incomes, decreased walking distances for harvesting and fuel wood collection, trees providing *shade and accommodation* for human dwellings and for walking to and working in the fields, etc.
- The protection of *cultural values*, e.g. social ties, is maintained through the distribution of produce and provision of food, e.g. for feasts.
- Trees are provided for recreational activities particularly for of children.
- Increased *self-sufficiency* of food (also meat), timber and fuel can be achieved on a local but also regional and national level, when improved AF is practised in other regions, too, at the same time taking pressure of existing forestry resources as a cultural factor.

5.2 *Interventions for sustainable use of natural resources in the AFS - a general view*

In the following table a general view is given about important long and short term interventions to achieve a sustainable AF on site. To avoid repetition it is not distinguished between interventions that have to be done from the socio-cultural, economic or ecological point of view, because most interventions, like those under crop diversification, combine each of these aspects at once.

The following measures are primarily directed towards ecological and economic sustainability, particularly the increase of the production capacity of the soil and diversification of the system.

Additionally they have been selected in terms of their economic viability in the local situation of the farmers and social acceptability/ adaptability which is in part expressed in the two categories of long and short term measures.

It is differentiated in broad groups of ways and means like crop husbandry, physical measures and crop diversification. These groups have some salient points of improvements in common, so that they are already mentioned in each headline and only additional aspects are mentioned for each single intervention. Hints for further explanations concerning each of these interventions are given in the third column.

Legend:

Term:

S = intervention that can be realized in the short-term with no or very few external inputs

L = interventions for the longer term that may need higher material inputs, particularly better knowledge and management skills

Confer for further information:

3 = explanation of traditional measure can be found in chap. 3

5 = explanation of intervention can be found in chap. 5.3

app. = additional information to species can be found in app.3

TERM	INTERVENTIONS/ PRACTICES	SALIENT POINTS OF IMPROVEMENTS	CF.
	Better crop husbandry	• **improves productivity per land unit**	
S:	Manual clearing, pruning and pollarding of trees	• reduces erosion (stumps are left) • increases diversity	3
S:	Minimum/ zero tillage (best combined with mulching)	• reduces erosion • cheap, saves work and time	3
L:	Rational plant/seed selection and improved supply	• improves plant health, size, quality • Reduces risk.	(3) 5
S:	Rational crop selection (socio-cult. and agronomic concerns)	• stability reduces losses • reduces erosion	(3) 5 app.
S:	Pay more attention to seasonal changes (Hok, Hea, Mide)	• reduces erosion/ impact of floods • optimal use of growing conditions	(3) 5 app.
S:	Better seeding/ planting techniques (e.g. not too deep/ shallow/ with water, better spacing of crops)	• improves growth environment and production per unit of land and water • saves time, energy and work • can extend growing period	5 app.
S:	Mulching with live/ dead and imported /in situ mulch	• improves organic matter (fertility) • reduces losses of water and soil • improves growth environment of crop	(3) 5 app.
L:	Better pruning and re-grafting	• Increases yields and quality of tree crops	5
L:	Re-/ introduction of improved cultivars and crops	• saves work, • extends growing season	5 app.
L:	Better pest control	• Reduces risk of losses	5
S:	Better weeding	• reduces losses and erosion	(3) 5

TERM	INTERVENTIONS/ PRACTICES	SALIENT POINTS OF IMPROVEMENTS	CF.
	Physical measures	• **reduce erosion and water run-off** • **increase long-term productivity**	
S:	Any or in situ burning, leaving leaves and other org. matter on the surface	• reduces losses of nutrients • reduces CO_2 emissions • avoids risk of uncontrolled fire	5
S:	No further forest clearing of steep lands/along creeks and rivers	• maintains manifold economic, socio-cultural, and ecological benefits of forests	3 (5)
S:	Contour farming on gentle slopes	• easier to work the land	5
S:	Placing logs and individual terracing	• leads to terracing and easier to work the land	5
S-L:	"Faya Juu" Conservation (bund system) on slopes >8-30%.	• improves infiltration and drainage • makes farming operations easier	5
L:	Bench terracing on slopes >8-30%	• once established reduces work	5
L:	Buffer grass strips	• improve path infrastructure	5
S:	Better water control (small scale drainage or irrigation schemes, and runoff harvesting)	• sustainable/ more efficient use of water • creates better plant environment • extends growing season and plant production • alleviate risk of droughts	(3) 5
	Crop intensification and diversification	• **optimizes production per land/water unit** • **stabilizes the system** • **conserves/promotes biodiversity**	
S:	Multiple/ mixed cropping and likewise intercropping/alley cropping	• reduces erosion • improves growth environment of crop • reduces risks (e.g. of pest infestation) • divides labour better	3 5 app.
S:	Improved crop rotation, (esp. with cassava and legumes)	• creates better root environment • increases nutrient (N/P) availability • reduces pest and disease incidence • important famine food or protein	(3) 5 app.
S:	Integrate more deep-rooting perennials (fruit trees, leafy green vegetables, multipurpose trees, bio-fuels, live fencing and hedges, cash crops, medical plants) permanent polycultural orchards on steep slopes and along streams	• prevents erosion/ mass-movement, promotes nutrient cycle, surface water regeneration and establishes microclimatic balance • helps to overcome seasonal food shortages • meets manifold subsistence needs • enables higher cash income • serves as vegetative barrier /mark/shade	3 5 app.
S:	Re-/introduction of improved cultivars and crops, use of the greater variety of endemic plant species instead of introduced ones	• increases stability, saves work • can extend growing season • prevents expansion of nonindigenous species • conserves/ promotes genetic resources	(3) 5 app.
S:	Selective weeding	• supports beneficial species • promotes rapid regrowth of trees	3
S:	Sustainable gathering of wild food and non-timber products (esp. on steep lands/along large creeks)	• preserves manifold service, and production functions of forests • supplements food, material, income	3 5

TERM	INTERVENTIONS/ PRACTICES	SALIENT POINTS OF IMPROVEMENTS	CF.
	Improved plant nutrition system	• **increases soil fertility and productivity per land unit**	
S:	Planted/ intensive diversified fallow with NFTS	• reduces erosion and pest problems • recovers soil fertility and structure • provides manifold uses of fallow • Prevents establishment of grassland and/or (non-indigenous) invaders	(3) 5 app.
S:	Include more leguminous vegetables/ ground covers	• reduces erosion • better use of available resources • provides food (protein), fodder, timber, mulch, live fences	(3) 5 app.
S/L:	Supplement organic nutrient reserves (animal manure, compost and mulch)	• improves root environment • reduces danger of pest infestation	(3) 5
L:	Integrate minimum use of mineral fertilizers and herbicides	• improves nutrient availability • prevents soil degradation	5
L:	**Mixed farming: include animals into AFS**	• **prevents overhunting** • **improves nutrition** • **effectively uses natural resources**	**5**
S/L:	Integration of livestock	• makes effective use of available resources • provides ideal food storage • improves income	5
S:	Game farming	• additional food supply • furthers traditional customs	(3) 5
L:	Tethering or penning pigs and goats at all times	• prevents deforestation through consumption or destruction of tree saplings and seedlings • prevents damage to gardens and erosion • effectively produces manure	5
L:	Integrate fish farming and bee keeping	• provides important protein /energy resource • reduces dependency	5
	Appropriate modern technology and non-farm economic development	• **increases income and self-reliance**	
L:	Renunciation on use of inappropriate 'auto'-mechanization but appropriate technologies for cultivation	• prevents dependency and waste of expensive external energy • avoids soil destruction • offers equal opportunities	5
S/L:	Improve harvesting operations, storage and processing	• reduces harvest losses, seasonal shortages • levels out prices and income	5
L:	Promote other sustainable economic development activities	• provides alternative jobs for young and old • increases stability of income	5

Table. 7: Interventions and practices for sustainable use of natural resources in AF and salient points of improvements

5.3 *Explanation of interventions, their economic viability and social acceptability*

Some of the inventions that are listed in table 7 are traditional methods, such as manual clearing with pruning and pollarding of trees, minimum/ zero tillage, selective weeding, multiple and mixed cropping. These methods have been sufficiently explained and evaluated in chap. 3 and are therefore not repeated in this chapter, although they must be further applied as they also provide many benefits under land scarcity. In this chapter the background of the present state of knowledge is analysed for innovations and improvements that are particularly concerned with more permanent cropping and integration of livestock.

5.3.1 Better crop husbandry for improving productivity per land unit

It is expected that improved crop husbandry can make major contributions to raised productivity, even if land quality decreases (BEETS 1990, 258). It is important to note that the technology and the means to improve crop husbandry are already available or, in principal, within reach of Gurakor. For example, it is estimated that improved weeding can improve productivity. What is required in the investment of a hoe? It merely seems to be the change in mentality and better management through training that is needed as input.

Rational plant/seed selection and improved seed/ plant material supply

Better organized and rational seed selection according to yield size and amount of fruit, growth and health of the food plants have to be propagated to provide a self-sufficiency of locally adapted and robust varieties with better pest and disease resistance than imported high yielding varieties (=HYV) which suffer from many inherent weaknesses such as high needs of fertilizer, chemical pest control etc. Such seeds then have to be handled properly (cleaned and dried) to prevent damage by insects and pests. To enhance the process of seed selection some promising wild forms such as the different nut trees, wild vegetables or multipurpose leguminous trees (cf. app.3) should be tried out and selected at ATS, community schools or by the farmers themselves.

Rational crop selection

To choose appropriate crops for the right place according to biological and agronomic aspects including crop characteristics, climate, soil and land type is very important to maintain or increase the stability of yields. Therefore further crop suitability studies would be necessary, e.g. for rice and other traditional or introduced crops. However, better marketing of such site staple crops is the precondition, as rational crop selection also involves socio-economic and cultural aspects like cost of production, cost of marketing, prices and familiarity with the crops, as well as cultural, nutritional and multi-purpose value of different species. E.g. cassava may be of lower nutritional value than taro or banana, but is very productive in spite of declining soil fertility. It is further an important famine crop and can be stored after processing. Yam, which is much more demanding to soil conditions has the positive characteristic to be storable without processing. To

match crops with the physical environment, with villagers' needs and socio economic conditions extensive use should be made of app.3 which shows for a great range of available species different demands (on soil and light), invasive behaviour and values for special purposes.

Paying more attention to seasonal changes

Rational crop selection also includes paying better attention to seasonal changes. For instance, to plan cropping systems in such a way that crops are precisely matched at the right time is a way to make maximum use of the natural resources like ancestors in Gurakor did with their traditional calendar. As a result, stress such as drought will either be avoided altogether, or when it does occur, the crop will be at a stage where it is tolerant of it. Erosion can also be prevented through establishing soil covers before the onset of the wet season. As the traditional calendar showed some people still have a good understanding of the interactions between crops and seasonality. In addition it is important to be aware of probable periodic droughts (e.g. caused by El Niño). For plating schemes app.3 can help to make effective use of different crops and trees that are for example drought resistant or have a complementary seasonality than most traditional staple food crops, to ensure constant supply of food throughout all seasons.

Better seeding and planting techniques

Attention has to be paid that seeds or plant material are not placed too deep, shallow or too close to stones or other obstructing material, particularly when sowing is done in a rough seedbed. Further crops should be better placed (cf. app. 3) as, for example, overplanting leads to interplant competition in the early growth stages and too wide spacing is a waste of land and increases erosion or weed growth. Correct plant population management can easily give yield increases of up to 30% (BEETS 1990, 463) and only needs know-how and management as input.

Another method to ensure a better growth environment and to extend the growing period of a crop and so enable higher yield is 'water planting'. If there is a creek or other water reservoir nearby crops can be planted with a measured quantity of water (about 3 litres per planting hole) into an otherwise dry soil, some time before the time of the rainy season. Especially on sandy soils on alluvial plains in Gurakor with a high water table this method can help to link the water applied with moisture in the subsoil. As the method is simple, cheap and effective it can and should be applied by many smallholders in Gurakor, who however, first have to acquire the knowledge of such a system.

Mulching

As shown in fig. 30 dried grass, leaves, coppiced branches of trees and other plant remains for mulch are necessary to enhance infiltration, lower evaporation, run-off and therefore erosion, regulate soil moisture-and temperature regimes, to improve physical and biological soil properties and thus enhance soil fertility and yields. Fertility maintenance is particularly achievable through utilization of legume covers as live mulches. This cultural practice known as green manuring is explained below under plant nutrition.

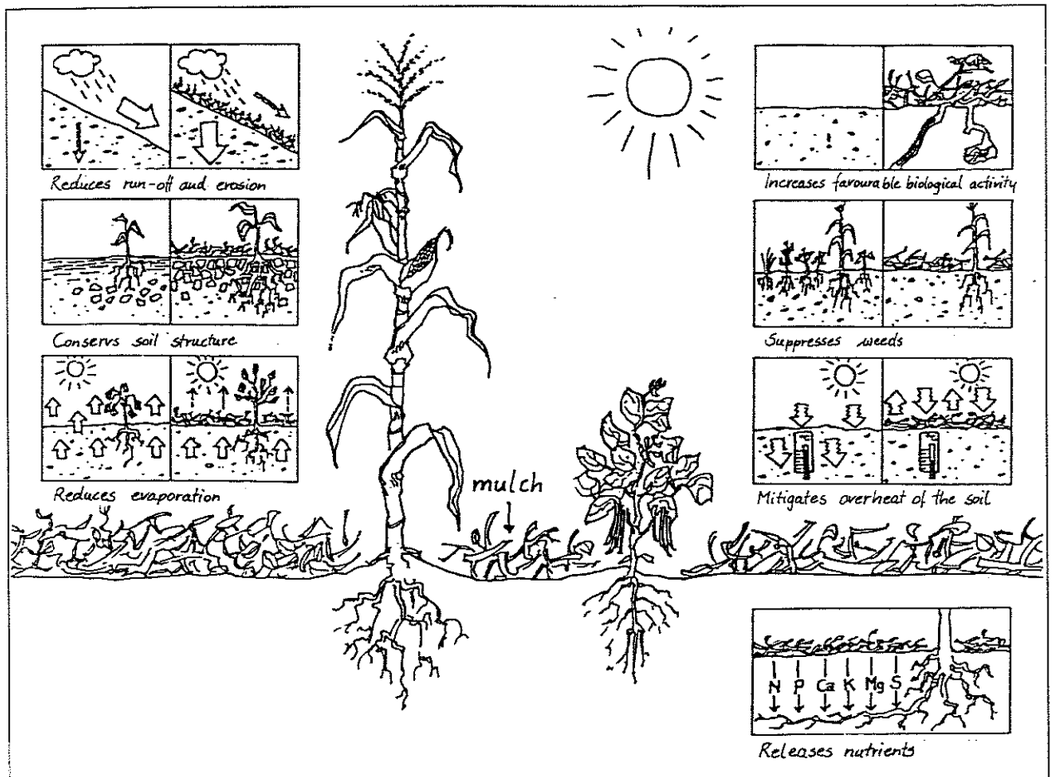

Fig. 30: Effects of mulching (modified according to MÜLLER-S. et al. 1986, 279)

Better pruning and re-grafting of crop trees

Better pruning of coffee trees, *Leucaena leucocephala* or other leguminous perennials, can greatly enhance the output not only in coffee plantations as it stimulates increased regrowth. Top working (re-grafting) of existing or newly planted fruit trees with better varieties can easily improve yields and quality of crops, but needs good knowledge and skills.

Better pest control

Mixed cropping instead of monocropping is the precondition to control pests through natural enemies, parasites or predators as explained in chap. 3.2.4. It is best to let nature look after itself as it has for many millions of years, since chemical pesticides would kill both bad and beneficial insects and animals that feed on pests, and make pests become more resistant to these chemicals. Since different types of crops are grown in mixtures it is difficult to apply specific pesticides and herbicides, which are besides far too expensive for subsistence agriculture and resource-poor farmers. Direct exposure and imperfect use of pesticides or ingestion of contaminated foodstuffs can be a health hazard to human beings.

Besides the traditional methods, repellent plantings can further improve biological pest control. Repellent plants bestow some protection on nearby crops, up to a distance of one metre. Some

repel a wide variety of insects and others are effective against particular pests (cf. app. 3). Other possibilities to control pests are the use of resistant varieties, but these are not easy to get, or to take advantage of insects' natural cycles (e.g. to grow certain crops in seasons when the pests are not there). Damage through larger and small pests can be reduced by luring them into *traps* or by setting up barriers and borders (e.g. against wild pigs), wrapping crops (e.g. against fruit bats) or just collecting them like the Giant African Snail which then provides valuable fodder for pigs. If pests should become a serious problem there are still many ways to produce repellents or insecticides themselves, e.g. with garlic, other alliums, pepper and a range of plants that grow in gardens, that cost nothing and are not poisonous (for further information GOELTEN. 1990, 199pp).

Better weeding

Especially during the critical stages of crop establishment, weeding can significantly increase yields. An experiment in tropical India showed that weeding should best be done 20 days after crop sowing to reach significantly higher yields[46]. In Gurakor, better tools, like better shaped hoes, etc, can help to lighten this work. it has to be evaluated that on the one hand, it is good to weed a field after a crop has been harvested so that the next crop will have fewer weed problems. On the other hand, weeds esp. composites help to decontaminate the soil and they can have an ecological advantage of protecting soil from erosion when the plot is not immediately replanted.

5.3.2 Physical measures for erosion and water control

Any burning or at least in situ burning

When cropping periods are extended and the fallow ones reduced, it is important to avoid the burning of slash and leaves to prevent grass invasion, solar voltarization and much of the nitrogen, sulphur and carbon to be lost in the smoke instead of being used for mulching or production of compost. During the end of the dry season and especially in times of severe droughts, burning must be an absolute taboo to prevent severe impacts of uncontrolled fire (cf. chap. 2.1.4, 3.2.2). Further it has to be prevented that the soil lies bare and exposed to heavy rains through burning at the beginning of the rainy season. When burning still shall be applied after fallow periods with woody regrowth it should always be done on the plot and not as often practised at the edge of the field where ashes will just be leached. Burning then helps to sterilize the soil of pests and enrich it with phosphorus and nutrients released from the ashes.

Contour farming:

Planting crops along contour lines e.g. on ridges and furrows is appropriate on gentle slopes to prevent soil erosion. This type of planting can either be done with different annual crop types (cf. 'intercropping') but preferably with a mixture of annual or perennial crops (cf. 'alley cropping').

[46] when weeding was done 20 days after cropping a 1.0 t/ha yield was reached compared with 0,2 t/ha on an unweeded plot and 0.3 t/ha when weeded after 50days after sowing (BEETS 1990, 466).

Likewise buffer-grass-strips could be promoted if walking spaces are left in between the rows (cf. fig 31).

(Bench terracing)

Although the age-old terraces of the nearby Philippines and Indonesia are world famous for the sustained production on otherwise steep slopes it is often claimed that this method can cause considerable environmental deterioration when they break. Further new terracing would change the soil profile, the topography and water household when not properly designed. Thus bench terracing is a controversial subject and as in PNG farmers have no experience with this method it is unlikely that it will succeed without expert instruction. Therefore the two following simple but effective methods seem to be more promising:

Placing logs

Logs can be placed along the contour in the garden area as it is done in some areas of PNG in the highlands so that they prevent soil erosion (cf. fig. 31).

Individual terracing

Likewise individual terracing, that is lining of stones around individual tree crops or with the help of an A-frame along small plots can help to prevent soil erosion (cf. fig. 31).

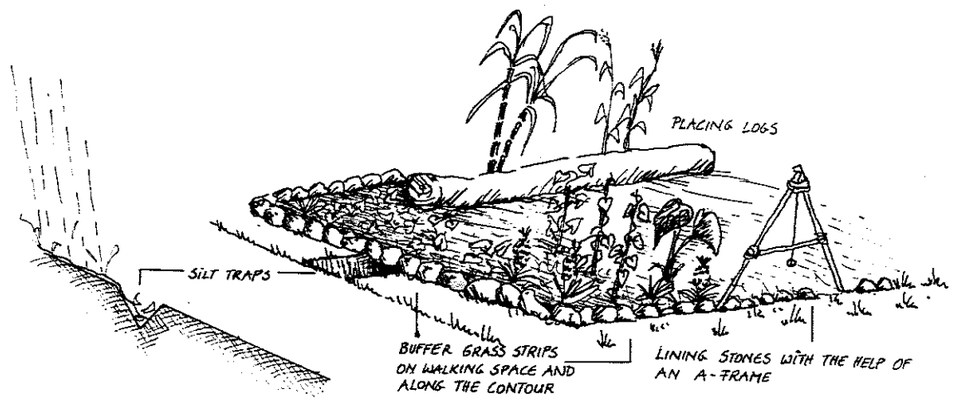

Fig. 31: Simple physical measures to prevent soil erosion

'Fanya Juu' conservation

As shown in fig. 31 the 'Fanya Juu' bund system for soil conservation, developed in Kenia, can be another promising alternative to bench terracing (cf. BEETS 1990, 512p). It can be easily done by farmers themselves with the aid of local extension workers. The bunds are made about

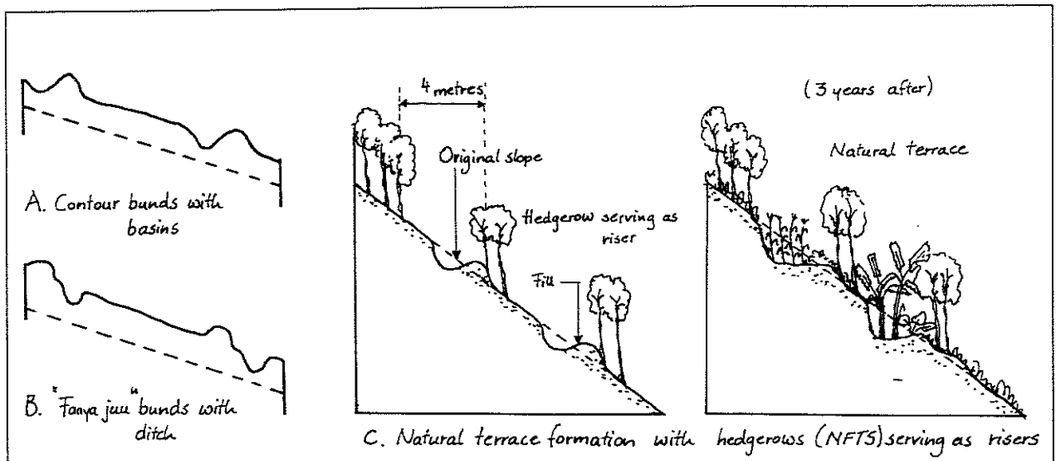

Fig. 32: 'Fanya Juu' bund system for soil conservation and natural terracing (modified acc. to BEETS, 513).

0,5% of the contour so that excess water is gently drained off. The bund is about 0,5-1,0 m in dimension and the soil from the trench is thrown upwards, and not as usual downwards, to form a bund (cf. fig. 32 A+B). Any run-off water is stopped by this bund and allowed to infiltrate. Deep rooting perennials (like leguminous trees) should be planted on the bund to hold the soil. The strips between the bunds then tend to flatten over the years, becoming a series of terraces (cf. fig. 32 C). This increases the stability of the soil and makes farming operations easier and more convenient. Terraces may be formed even naturally when rows of trees are planted without any earth movement.

Water control

More control over the moisture balance means two things in relation to the environment:

1. Better growth conditions and thus a possibility to have better crop cover during the year; and
2. less run-off, which means less erosion.

More control over the moisture balance can be achieved in two ways, namely through conserving the available rainfall in situ and through irrigation. Any measures for soil conservation like contour farming, mulching or the 'Fanya Juu' bund system, which have been explained above almost always mean at the same time water conservation, since run-off, taking away water and soil, is reduced.

Drainage systems

In some garden areas it may be helpful to get rid of excess water through grassed waterways, but due to good drainage of most soils in Gurakor and other measures that increase the infiltration rate, this measure may only be necessary in very few cases and should then be combined with the setting of silt taps to trap all soil or silt washed away by the run-off water (cf. fig. 31). It could then be used as a dropping place for weeds and from time to time be transferred back to the garden beds.

Small scale irrigation schemes

Small-scale irrigation schemes like the traditional irrigation of watercress or taro is a very promising technique to increase yields as explained chap. 3.3.3. On the whole irrigation is a beneficial effect to the environment since it increases soil cover and often reduces run-off. However, often, irrigation physical works are not properly constructed and they lead to silting up, water erosion, leaching out of nutrients and depletion of bases. Still better growing conditions are reached through accelerated soil weathering, possible addition of nutrients with the water, on sandy soils and enrichment with silt and clay. This leads to promotion of plant growth and therefore better ground cover and humus production. Moreover plant growth during the dry period is made possible. The layer of water standing on the soil protects it against sun and against too rapid breakdown of humus. Those irrigation systems have to be in balance with the natural capacity of the creeks to supply water subsequently and should not stay in conflict with the need for clean and sufficient drinking water. There are some farmers in Gurakor who know to construct and maintain such systems and a great deal can be learned from these persons.

5.3.3 Crop diversification and intensification

Crop intensification[47] and diversification[48] of subsistence production is not only necessary to increase and optimize plant production per land unit/ water, it is also the best way to solve the problems of deteriorating nutrition, fuelwood shortages and other needs, to stabilize the system and to conserve/promote biodiversity. Traditional multiple cropping that was explained above is important throughout the tropics in all stages of intensification and should therefore be continued. Very similar methods are explained here.

Intercropping

Intercropping is the growing of two and more crops simultaneously on the same piece of land often in a row to gain higher and more efficient use of nutrients (BARBIER 1990, 41). Similar ecological as well as economic benefits arise like in mixed croppings (e.g. pest control). Especially when planted along the contour, the optimal combination in time and space of leaves and root systems, nutrient supply and soil cover prevents soil erosion and leaching of nutrients; and effectively uses synergetic effects through symbiotic relations. Legumes should play an important role in intercropping but are not necessarily integrated[49] (cf. fig. 33). These experiences of intercropping systems are not only based on scientific research but also on farmer's experiences. Some possible companion plantings of crops that complement each other are shown in app. 5.A.

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[47] Crop-intensification that is, more crops and higher output per unit area.

[48] Diversification, that is, increasing the number of crops or production enterprises per farm.

[49] Already the combination of maize with beans rises the yield to 20 % in comparison with mono cropping, when three different crops are planted yields rise to 40-45 % surplus. because sweet potato grows best in light shadow, provided by maize and maize profits from N-fixation of the beans (ROTTACH 1984).

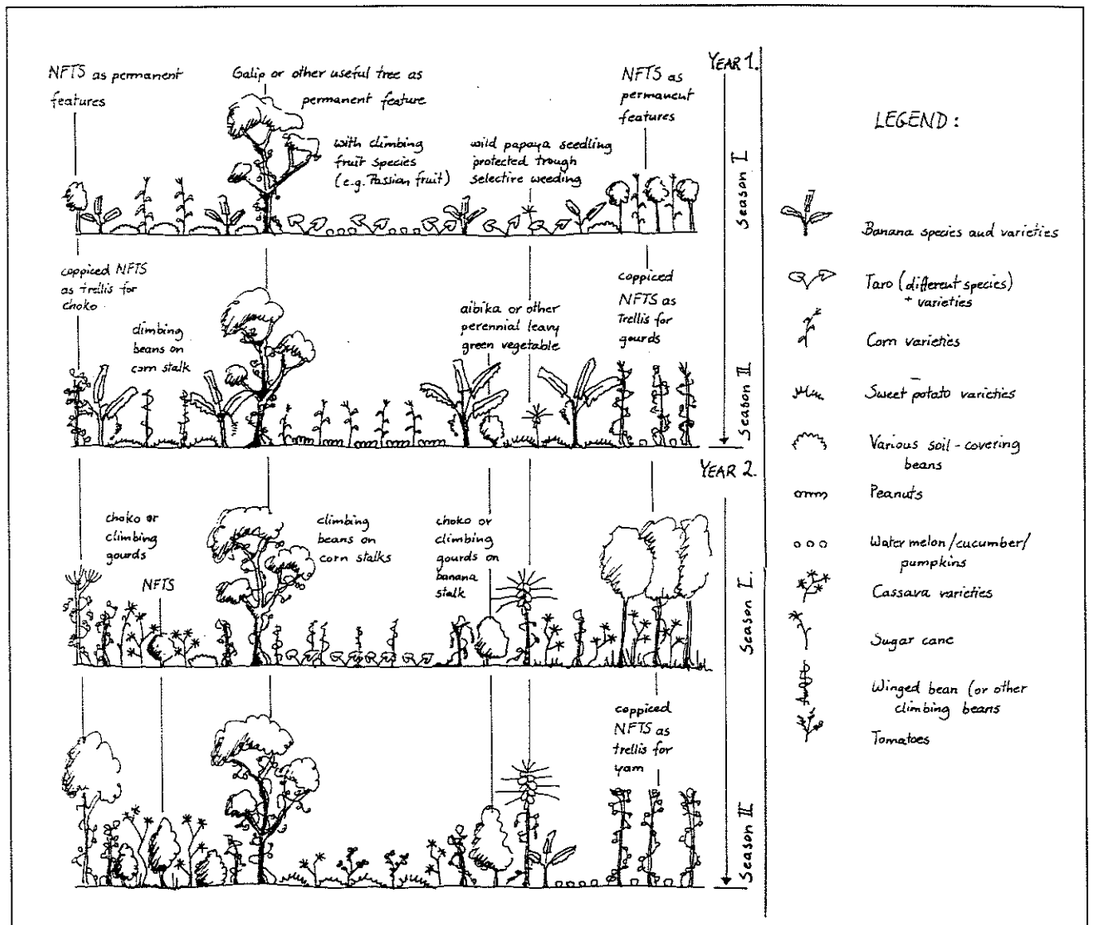


Fig. 33: Example of a cropping sequence with the establishment of leguminous hedgerows

Alley cropping

The most investigated direction of AF research is alley cropping with nitrogen fixing tree species (=NFTS) and shrubs that can be pruned, intercropped by annual crops like corn and climbing yam. Whereas the rows of trees stabilize and enrich the soil in the space in-between (alley) sustained production of crops is allowed. Frequent cuttings of the top parts should be used as green manure to cover and enrich the soil with nitrogen and prevent evaporation of water and soil erosion throughout the cropping cycles. In addition prunings can be fed to rabbits, goats, pigs, etc., the pruned stems can serve as sticks for yam, beans, choko, vanilla and other crops (cf. fig. 33) or as shade trees and for fuel wood production. This method is not totally new to local farmers but only used within coffee plantations. A disadvantage may be the high labour and management requirements.

Improved crop rotation

Alternate cereal or root crops with legume crops have similar effects of stabilizing and increasing yields like mixed cropping systems, because the different crops take up different nutrient resources and they have different pests etc (cf. fig 33). Bananas, yam and taro have to planted first after controlled fallow because they need better soil structure and fertility. It is important to include crops that are resistant to root-knot nematodes. Since they attack root crops like peanuts, sweet potato and other vegetables it is important to plant other vegetables like corn, watermelon or banana in the rotation (cf. WELLS 1991, 73pp). The longer the rotation cycle, the more beneficial it will be for disease reduction. A rotation cycle may for instance contain: 1. banana - 2. peanuts - 3. corn – 4. pigeon pea – 5. yam – 6. watermelon - 7. cassava – 8. intensive fallow. Another very effective control measure against pests on small fenced plots would be a 3/4- year rotation which includes a fallow year as chicken yard[50] (ibid.).

In intensive bush fallow systems cassava can serve as a transition crop to the fallow cycle and extend the duration of cropping (cf. fig 33). When maize/cassava intercropping is planted as the last crop, maize will be harvested after about 3 months whereas cassava continues to grow. Cassava will be harvested when needed and the harvest can stretch over 8-18 months, after which other crops can be sown/planted again. The regenerative effect of cassava is attributed to its deep rooting, which mobilizes additional nutrients from lower soil layers and its high Al-toxicity tolerance. It can make phosphorus (=P) available which is a restrictive factor in most of Gurakor's soils. The deep tillage associated with harvesting of the roots permits incorporation of organic matter and deeper rooting of the following crop. The considerable leaf drop of the cassava plants fertilizes the topsoil and a dense cassava stand may also shade the soil sufficiently to suppress weeds[51].

Including more deep rooting perennials through agroforestry or multi-storey planting

The manifold benefits of AF with the deliberate planting of trees was already explained above as it is the overall principle of tropical farming. In this section only the need and benefits of tree crops that should be planted for their special production functions will be further explained.

Planting of more fruit and nut trees and perennial leafy green vegetables

A wider range and higher quantities of introduced and preferably indigenous trees that are well adapted and provide fruits, nuts and edible leaves (cf. app. 3 H, I) should be planted. Not only that they bear a culinary value, more use should be made of their potential to counter the rapid increase in nutrition -related maladies and disorders among the villagers. Increased consumption of fresh fruits, nuts, vitamin-rich green leaves, derived juices, and complex-carbohydrate-rich

[50] The chicken house could then be set in the middle of the four plots with doors opening into each of the tree plots.

[51] However, the question remains whether cassava really contributes to a regeneration of the soil for sustainable cultivation or only exhausts the soil more completely.

and fibre-rich staple foods such as bananas, breadfruit, and coconut (which has no animal fat or cholesterol) are exactly the types of foods needed to Gurakor's dangerous nutritional transformation. These foods also constitute the traditional snacks, drinks, and supplementary foods that are now being replaced by soft drinks, candy, and other modern but nutritionally-poor processed foods. Other positive effects of tree crops are to lengthen the time-span of production, that they demand less labour requirements for maintenance than annual crops and the insurance of a diversified reserve of (famine) foods should annual crops fail.

Planting trees for fodder, timber, fuel wood and other purposes

According to the increasing demand for energy, timber and fodder renewable resources have to be provided by AF. In general, trees may be considered suitable to AF if they complement and support rather than compete with the interplanted food crops. Therefore most leguminous or other nitrogen fixing trees species (=NFTS) are best suited due to their function as site reclamation and amelioration and their multi-purpose, like nurse cropping, green manure and sometimes even food. Not only the commonly recommended and tested introduced species of *Leucaena, Albizia, Gliricidia*, and *Calliandra* or the indigenous NFTS *Agathis spp., Araucaria klinkii, Casuarina oligodon, Endospermum spp.* should be used. Other indigenous multi-purpose NFTS that remain scientifically untried in AF (e.g. *Acacia acutiformis, Adenanthera pavonia, Erythrina variegata, Parasponia rugosa, Pterocarpus indicus, Schleinitzia novo-guineensis*) should also be integrated and tested. Indigenous NFTS should be preferred because their multipurpose function for extracts, material for handicrafts, aside from those uses mentioned above, are better known and valued by the people and are already available, whereas seed and plant material of valuable introduced ones are frequently not within the reach of subsistence farmers. Great caution must be taken with introduced NFTS as many of them are likely to threaten biodiversity through invasive behaviour. When livestock is included in the system various leguminous fodder trees play an important role in human food security through their function as animal-feed sources and as drought reserves. In a wider context, these plantings serve to reduce pressure on forests, protect hill areas. With increasing fuel wood shortages, the production of charcoal out of fast growing NFTS could be a cash income in the near future and timber could be sold as poles or for the production of pulpwood.

Leguminous or other trees and shrubs should be used for living fence posts, lining animal pens, either with or without wire or around crops susceptible to damage by livestock, as boundary markers between different landholding groups or individual plots within a given gardener's active garden area. They can at the same time serve as productive and ecologically valuable component of the AFS.

Biofuels

Besides fuel wood and charcoal supply through replanting of trees, the production of biofuels could be an appropriate energy supply in PNG, since the frequently lacking maintenance of technological solutions such as solar energy or hydropower projects in PNG is a problem. Such biofuels would be based on locally available biomass resources, such as producer gas, alcohol made of fish tail palm sap, or palm oil that can be used instead of petroleum. This would contribute to a renewable energy supply, to protection of virgin forest and a better control of negative effects on climate. Further it would make economic use out of well-adapted traditional species of PNG.

Planting of cash crops with subsistence ground or tree crops

Since there is more scope for producing cash crops such as mango, galip-nuts, kapok, spices like vanilla, nutmeg, cinnamon, timber, and resins, besides long established major export crops such as coconuts (for copra and oil), bananas, coffee, rubber, oil palm and cocoa they should be integrated as sources of cash income. To prevent the general trend that good soils are only reserved for cash crops, they should be planted in permanent groves on steeper slopes to form terraces (cf. 'Fanya Yuu' conservation). If grown in vicinity to homesteads they should always be intercropped and undercropped with food crops during the establishment stage and bananas, taro or other shade tolerant species being retained in mature gardens, as it is already practised in blocks of Robusta coffee[52].

Different tree crops themselves should be interplanted with each other (e.g. cocoa under coconuts, galip nuts or large fruit trees) or with climbing species using NFTS and *Cyathea spp.* (tree fern) trunks as nurse plants or climbing poles for kava, black pepper or vanilla[53]. Vanilla, given its high returns per acre and negligible demands on soil fertility as an epiphytic member of the orchid family, seems to be the perfect plant for Gurakor and other villages where land scarcity is increasing. Still farmers first have to be trained to manage these new cash crops. Local cash cropping with betel pepper, betel nuts and a variety of nuts and fruits is much more economically sustainable due to their much greater price stability compared with export cash crops and should therefore be paid more attention. Moreover, papaya, water melon, passion fruit, mango and other fruits can supply the country's growing demand for fruit, e.g. in tourists' resorts or can be processed to juices as better alternatives to imported canned soft drinks. Tobacco can be sold to local cigarette manufactures and, if there is sufficient international marketing spices like ginger, pepper, Cinnamon, Nutmeg, vanilla etc., or fruits and nuts can generate cash income.

Planting of medicinal plants

Medicinal plants, either traditionally used in Gurakor (cf. app. 3.M) or known from other areas of PNG) should be further planted and conserved in the AFS as it is well recognized that especially the psychodynamic aspects of illness, whether associated with organic disease or not, are best handled with traditional medicines and/or by persons sharing the same belief systems as the patient. Whether these persons are traditional healers, church pastors or merely other family members, they represent sources of therapy outside the official medical system which cannot be

[52] Studies by CARRAD (1982) in the PNG highlands showed that intercropping of root crops, bananas, and other crops with coffee, in a 15-year cycle, gave smallholder farmers almost twice the real income obtained from coffee monocropping.

[53] PNG has a small vanilla development programme.

suppressed (cf. JENKINS 1992; 391). Still, more research has to be done to help each region to find out what traditional medicinal resources may be available and acceptable in the modern context, so that elements of traditional medicine can be fused into the modern medical and primary health care system.

Permanent polycultural orchards on steep lands or along creeks

Preferably useful traditional species like marita, sago palm, ton, sis, okari, rosewood, candlenut, cut nut, coconuts, etc. that are best suited on lithoral or swampy places should be planted along creeks and rivers, whereas breadfruit, galip-nut, tulip, and a wide range of other fruit-, nut-, and other useful trees should be planted or promoted as polycultural orchards on steeplands to maintain the ecological equilibrium and to prevent natural hazards. Such land which is unsuitable for annual crops can thus provide, as far as there is a good marketing concept, better farm incomes (cf. 'Cash crops', above) aside from their many functions for self-sufficiency.

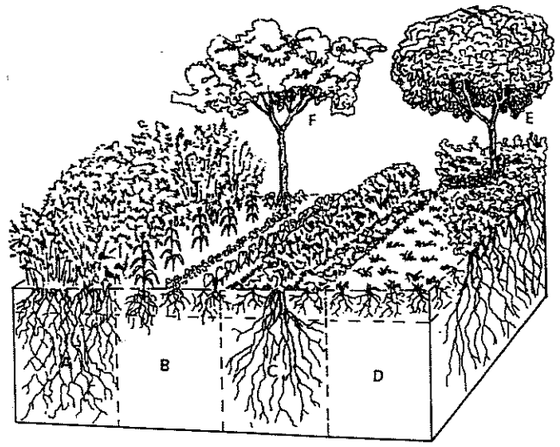
Re-/introduction of improved cultivars and crops

Modern science today has accelerated the tradition of selecting seeds from both wild and cultivated species on the basis of their yield, pest resistance and so on. The problem is that such 'high-yielding varieties' (=HYV) are generally much more demanding on their environment and susceptible to stress (BEETS 1990, 259) so that they have to be bred in 'best conditions', which means in conjunction with high external inputs (mineral fertilizers, pest control and/or irrigation) and high standards in crop husbandry. This is only possible with high levels of training and education and better cash incomes. Thus, traditional varieties that are usually better adopted to the environment cannot be neglected in improved AF, as they likewise respond greatly to improved crop husbandry, even without the use of high external inputs.

To reduce the risk of expansion of viruses and other diseases in traditional varieties that are vegetatively multiplicated, disease free seeds of in-vitro multiplication might in some cases be necessary and very helpful to reintroduce valuable traditional species. They can be received from a project in PNG that conserves and provides healthy seeds of a range of traditional cultivars including low productivity varieties and wild forms, which may later provide better seed material (talks with PETT 1997). Whereas such disease free cultivars are very important and useful in subsistence agriculture improvement as they enhance the productivity and conserve the diversity of cultivars, benefits of HYV are more critical and unstable because of the great difference between crop failure and high yield.

5.3.4 Improved plant nutrition system for increased productivity per land unit

Many measures mentioned above already contribute to improved plant nutrition. In this chapter the mechanisms are explained that replenished nutrients into the soil that have been removed by crops, and maintain a sustainable level of soil organic matter content especially when land pressure leads to more permanent cropping.



A = Improved successive fallow, with different kinds of deep-rooting, bush legumes, with high biomass production;
B = Mixed cropping; the harvest residues are worked in the soil;
C = Simultaneous fallow with a bush legume in the middle row and covering the soil with mulch;
D = Pasture for animal grazing (for production of stable manure);
E = Demarcation of grazing and cultivated areas by means of hedges of bush legumes;
F = Inclusion of tree legumes in grazing and cultivated areas.

Fig. 34: Possible ways in increasing and maintaining soil fertility in tropical cropping systems (as in BEETS 1990, 519, fig. 7.52)

Planted/ intensive fallow

As long as enough land is available, it is desirable to maintain an intensive shrub fallow of 3–4 years. Intensive fallow with planted or promoted NFTS and other particularly useful species instead of relying on natural regeneration is an important instrument to maintain soil fertility, but should be regarded as a complement rather than an alternative to other forms of fertilization. The use of appropriate soil-enhancing species that are tolerant to soil acidity such as the NFTS (cf. app. 3 J) is essential to restore soil structure, improve soil organic matter content, and increase soil fertility. Even a one year bush fallow cycle was identified as a very effective and sustainable measure for maintenance of soil productivity in intensive cropping systems[54], because it has positive effects on physical health of the soil and soil structure (cf. fig 34 A). The higher percentage of woody material in the bush fallow (compared to seasonal fallowing with only herbal elements) allows it to decompose more slowly, which is an important factor under the tropical conditions that lead to rapid decomposition (cf. chap. 2.1.5).

The rhythm of rotation has to be adopted to the local soil conditions and application of manure

[54] As a project in Nyabisindu showed the intensive green manure is most effective, whereas even high compost and manure application or mineral fertilization did not reach such high yields as after a well managed bush fallow (c.f. ROTTACH 1984).

and compost. Under poor soil conditions and low application of fertilizers, a 1:1 rotation (bush-fallow: crops) can be optimal and more effective through higher yields even if there is a 'loss' of 50% of land (ROTTACH 1984). According to the species planted in such a bush fallow it can still provide products such as fodder, (famine) food, compost, building and other material.

Another advantage of intensive fallow systems is that it appears to have high adoption potential among Gurakor farmers, since they do not trust systems without fallow periods.

Include more nitrogen fixing trees, shrubs and ground cover in the cropping system

The idea is to replace the succession of fallowing and cropping over time by a coexistence of plants in space: plants which 'accumulate' and others which 'consume' soil fertility. In this spatial arrangement, the accumulators might be deep-rooting perennials (trees or shrubs) or annual soil cover plants and the consumers are annual field crops (cf. fig 33, 34). Therefore extensive use must be made of the high yielding legumes which have a beneficial residual effect due to nitrogen enrichment and improvement of the physical and biological properties in the soil. It is scientifically proven that such leguminous species that provide green manures significantly increase yields[55] of neighbouring crops. Besides the NFTS (cf. app. 3 J) that were already mentioned above genotypes should be used that cover the soil better for the longer period of time, so that they have considerable advantages for the environment[56]. Plants that are already available like cover crops in coffee plantations or traditional/ recently introduced leguminous vegetables should therefore be more extensively used and tested for their effectiveness, since new breeds of such genotypes are not within the reach. Even if traditional species might not be the perfect cover plant they also maintain a regular supply of nitrogen-rich organic matter which is then incorporated in the soil for the following crop and additionally supply highly nutritional food with high amounts of protein which is a limited component in villagers' nutrition. Particularly promising species like the Winged Bean (cf. chap.2.2.6) and Pigeon peas (*Cajanus cajan*), that are very deep rooting and thus have good soil improving characteristics should be incorporated aside from many others that are listed in app. 3 D.

Application of legume inoculant, e.g. for soybean must be extensively explained to the farmers when they shall be planted because it can cost-effectively increase its production (cf. KESAWAPITAK 1991, 99).

[55] E.g. results from two year studies of PAISANCHAROEN et al (1991) in Thailand showed that when cowpea was incorporated into the soil cassava yields were more than doubled in the first year (119 %) and still increased 26 % over the control in the second year (cf. KESAWAPITAK 1991, 98pp). There are many more studies which show that *Leucaena leucocephala, Gliricidia sepium, Cajanus cajan, Cassia* and other species increase or even double yields of accompanied food crops (cf. ibid.).

[56] They should be vigorous, esp. during the first phase of the growth period, drought resistant so that they persist in the dry season, capable to perform under marginal conditions or low soil fertility, resistant to pests and diseases and stable. It is expected that recent advantages in breeding and achievements in genetic engineering will soon lead to such genotypes which will in practice, however, hardly be available for resource-poor farmers.

Supplement organic nutrient reserves

During the cropping cycle, organic fertilizer should be examined for supplementary use to intensive fallow and particularly in permanent cropping systems. Experiences in the HDC in Bundun since 1982, with the use of compost, pig, rabbit, and more recently external chicken manure on a restricted piece of land show that sustainable agriculture is possible without mineral fertilizers and fallow periods, as long as trees and legumes are included and there is a good plant husbandry in the close vicinity to homesteads.

Animal manure, although better suited than mineral fertilizers, is at the moment in Gurakor far too limited in supply to offer a real alternative as long as farmers do not include livestock. Still chicken manure of the nearby chicken farms could be used as cheap external fertilizer rich in available P and N to restore overused garden plots around the villages. At longer distances to the village bat manure which is very rich in P could be a good alternative and could be carefully taken from carves in Gurakor to be applied.

If such possibilities are not within the reach of a garden plot or a farm household, the possibility remains for all villagers to produce compost as organic fertilizer out of plant matter like kitchen and harvest wastes, ash and mulches. As composting is new to most of the farmers, education about compost production is most urgent to make effective use of this cheap local resource. Some useful materials for the use as organic fertilizer are evaluated for their NPK resources in app. 5. B.

Integrate mineral fertilization

With further land shortages, the application of external nutrients like mineral fertilizer might be necessary to sustain crop yields when the same piece of land is cultivated for more than 5 years (cf. BEETS 1990, 517)[57]. Still it is important to note that in tropical environments mineral fertilizers alone cannot maintain soil fertility and soil organic matter content in the long term (cf. chap. 2.1.3). Modest quantities of chemical fertilizers (such as NPK fertilizers), combined with other soil-improving techniques such as green manures, good crop rotation or organic fertilization can be very sustainable especially on degraded soils and could help to increase yields on land under cultivation. Thereby low-input strategies in fertilizer application in short periods of time are urgent to prevent leaching on vulnerable soils in Gurakor (cf. chap. 2.1.3), contamination of ground- and surface waters, reduction in soil organisms and nitrogen fixing bacteria (FAO 1988, 254). To prevent those problems, responses to fertilizers have to be assessed first. Therefore it is a precondition that a better developed farm support service and sophisticated management is available, which is at the moment quite unrealistic in Gurakor (cf. chap. 1.1.4). Thus it has to be doubted whether chemical fertilization is appropriate and sustainable in subsistence farming. Mineral fertilizers do not have a significant role in subsistence agriculture as long

[57] Also at the HDC external inputs in the form of chicken manure and plant residues of bought food are integrated.

as prices in PNG are high, there is insufficient infrastructure for transport, lacking credit and high risk due to erratic rainfall distribution and drought spells.

Still a more promising and effective method to increase yields remains in the application of compost together with small quantities of lime, as studies in Thailand proved (cf. KESAWAPITAK 1991, 96p). Lime, compared with imported fertilizer, is quite cheap and available on every local market[58]. It can increase P availability and cation exchange capacity the most limiting factors in Gurakor's soils. However, also this method needs good explanation and training of the farmers because deeper soil layers have to be reached. Otherwise root growth would be concentrated in surface layers, which then would lead to increased water stress and ineffective use of the rootable soil. When deep liming is done, it again has to be applied very moderately because it could otherwise lead to reduced availability of micro-nutrients and higher weed growth. Another negative effect of liming is that denitrification and decomposition of organic matter would be accelerated, which can lead to rapid leaching of the nutrients.

5.3.5 Including animals into the agroforestry system (mixed farming)

Integrate livestock husbandry

Integration of livestock as an important component into the crop based system of Gurakor is necessary for the long-term intensification as it provides high quality food (esp. protein which is often deficient) and valuable organic waste material for fertilization. Excess of unusable plant refuse, weeds, coppice, household waste and small sized cobs and tubers that are otherwise left on the field, can be used as fodder. Livestock should not only be used as a means of storing surplus crop production for times of scarcity or feasting but also for a regular balanced diet instead of relying upon imports.

Fig. 35: Family in Bundun keeping rabbits and pigs. Pig stable (background) and rabbit hutch in the main made of local material, 1997.

The integration of animal husbandry into household systems in a holistic manner improves the complementary or supplementary relationship between plant and animal production and increases total productivity. It thus leads to a higher ecological and economic stability of the agricultural production system, e.g. it provides cash incomes independent of season and not only the meat but also furs or feathers are of high value. The integration of livestock, however, requires more time,

[58] It is traditionally produced for consumption with betelnut and betel-pepper everywhere in PNG.

regular work and detailed knowledge, so that in practice it will be quite difficult to introduce animal husbandry to crop farmers in Gurakor and needs good training and supervision in the initial stage. Another constraint is the lack of cash because some investigations are necessary at the beginning. Still investments are affordable when small domestic animals, like rabbits that are introduced in the HDC and ATS (cf. fig. 35), guinea pigs or traditional pigs and poultry are bought instead of large animals like cows[59] and care intensive overbreeds (e.g. broilers). They can be kept in pens and stables of bush material and can feed on locally available fodder.

Game farming and hunting

if people are not willing to invest much care or any money the integration of wildlife to reach higher meat production is another alternative. They would not carry a risk for any investment or the environment, because they fit well into the ecosystem. A diversified nurturing of underexploited wild animal species (e.g. cassowary, the third largest bird in the world, cuscuses and possums, traditionally promoted larvae of insects) that are physiologically adopted should be further tried and attempts for captivity breeding should be made. Not much scientific research has been done in this sector and it is often hard to raise wild species in captivity[60]. The aim of game management or-farming is to reduce hunting pressure. In the cultivated areas, the continuation of a wildlife population depends on the maintenance of natural or semi-natural landscape features which are essential to provide shelter and food to some species. On steeplands or other areas that are not suitable for cultivation and fallow areas, game management or hunting with traditional methods, which excludes the use of automatic weapons and nets for mammals and birds, can be a form of land use which provides the landowner with income and/or food from fish, eels, wild pigs and fowl, insect larvae, birds, and other wild game. Thereby also traditional non-selective, unfair and destructive methods like fish poisoning should be totally banned. Tabooed areas must further be accepted for their religious aspects and to provide some regeneration pools. Villagers should also not take more animals, eggs, etc. than the natural increase in a wild population[61].

Another possibility of cash income without threatening wildlife is the licensed captivity breeding of rare species, propagated by Wau-Bulolo Butterfly Farming in PNG who then control that animals which are caught are not put on the market under false pretences.

[59] Many projects with water buffaloes in PNG and a "cow project" in Gurakor have failed, also because people are afraid and not used to such large animals with hooves that are traditionally not integrated in farming systems and afford higher management.

[60] In Australia there are already some Emu-farms and projects to raise wallabies. There were for long periods no restrictions on the keeping of captive wild animals, however, such keeping is now increasingly regulated with the legislation designed to implement the Convention on International Trade in Endangered Species (=CITES) which can hinder such attempts.

[61] In order to determine harvestable quantities, scientists have developed the concept of Maximum Sustainable Yield. However this presupposes that this quantity is actually known, so that regulation can be designed to ensure that these limits are not exceeded. However, this basis for calculating the level of sustainable exploitation is lacking in Gurakor.

Tethering/penning of livestock

Pigs and goats should be tethered or penned at all times to prevent damage to gardens and acceleration of deforestation through the consumption or destruction of tree saplings and seedlings. Poultry could be penned at night and allowed to forage during the day. Pigs and some other livestock are best kept in deep stables for most effective manure production. Animals stay in the same home allotment for three months, growing with their own manure and sufficient absorbent strew higher and higher. Through their weight the material is compressed producing anaerobic conditions in connection with the urine without much loss of important substances. Husbandry could also be kept on a larger communal pig-rearing area with individualized pens under coconuts, breadfruit, or other useful trees that provide shade, tethering and fodder. Small animal pens should be constructed of local materials such as coconut logs, bamboo, rosewood or other local timber (cf. fig 35).

Integrate fish farming and bees

Fish production in artificial ponds may be even more difficult to introduce in subsistence farming because of high inputs of knowledge and management skills but not necessarily fodder and material. They would in return provide high yields of protein, high quality fat and a good source of cash income. They could be fed on locally available fodder such as termites, larvae, wastes of maize, cassava and sweet potato. Trees lining the fish ponds provide leaves as forage for fish.

Bees that transmit pollen for plant fertilization could be bred to produce honey so that the high amount of money spent on sugar today could be reduced. Thereby, many leguminous trees would also serve as honey-producing trees.

5.3.6 Appropriate modern technology and non-farm economic development

Mechanization and technologies for cultivation

As minimum tillage is the best method, mechanization, for instance, with heavy tractors and other equipment designed for conditions in temperate countries, proved quite unsuitable for tropical conditions (cf. BUDD et al. 1990, 335) or even impossible because of the terrain and tree stumps in the fields. Besides, such machinery can neither be afforded nor maintained. Even Asiatic Water Buffaloes as draught animals are very difficult to introduce, as it was experienced in some pilot projects in PNG, and, when used for land preparation, increase erosion. Therefore, selected modernization with affordable or mainly locally-made equipment is necessary. For instance hand tools like spades or hoes can lighten the work or water cans and wheelbarrows can facilitate transport in between cultivated lands. Further it is necessary to construct effective compost stockades, simple nurseries and fibre pots that can be easily made out of local material The 'A-frame' is another example of a simple tool that helps to construct garden-beds on levelled terraces or on contour ridges (cf. fig 31).

Improve harvesting, storage and processing on the local or regional scale

To reduce harvest losses, control over maturity of the crops should be improved. Therefore shorter distances to the fields are necessary, which can be reached through more permanent cropping. Pigs or other animals should serve as cheap storage as explained above. Dryers or other new crop conservation and packaging techniques might be very helpful to improve storage and overcome food shortages but investment and energy costs are still prohibitive factors for a wide dissemination. Still, simple solar dryers (e.g. made from bamboo with a cover of white plastic or just on a metal sheet exposed to the sun) where no rain can interrupt the drying process can be used to dry seeds or slices of fruits. Another often traditional way to prevent seeds or other food stuff from decaying is to smoke them. In this way insect attack is reduced. The dried seeds should be stored in a tin or plastic bag which is absolutely waterproof and where no insects or other external influences can destroy them. With increased surplus production for urban markets, storage has the additional function of levelling out seasonal price fluctuations. Small-scale processing of sugar cane would be a good way to produce sugar for the villagers' increasing need and to avoid dependency on expensive refined sugar.

A high degree in self-sufficiency in food production is a worthwhile objective, but complete self-sufficiency might not be a good strategy, because there are always certain products needed by a household which are difficult to produce on a smallholding, like salt, that can be traditionally produced in a very time-consuming process, or cooking oil. Thus it is desirable that processing is done by a central manufacture or factory operated by specialized managers, e.g. food fermenting, or by small rural based cooperatives (e.g. for coffee or sugar processing, drying, or oil extraction) largely owned by the farmers themselves. Inter-regional trade would be in many cases more efficient.

Another example for appropriate processing of AF products is the local manufacture of wood-burning stoves that use significantly less fuel than the very inefficient traditional stoves that lead to excessive use of wood and high labour inputs. What is needed for their introduction is education and extension campaigns.

Promote other sustainable economic development activities

To generate further and stable cash income besides the marketing of AF products and processing of food, more emphasis should be placed upon other local manufactures, provision of services, and small-scale businesses. For instance, community-based small-scale logging with portable sawmills adaptable to socio-cultural issues and ecology might be a good way to generate cash income and to prevent large-scale logging or mining projects with their negative impacts. Sustainable and appropriate tourism could be another possibility in Gurakor for sustainable economic development activities. Indeed Gurakor has a lot of natural attractions to provide like the large mountains covered by secondary and to a large extent virgin rainforests, dissected by narrow valleys with their clean and sparkling creeks, rivers and waterfalls. Such sites of exceptional

natural beauty are exactly what a growing number of tourists, that are heading off the beaten track are looking for. This trend can favour biodiversity conservation when the tourist activities are well regulated, because visitors contribute revenue and often lend political support for local and national efforts to protect natural areas. Travellers are increasingly curious about local people's knowledge of the forest. Thus bush tours could be accompanied by bilingual local guides who are knowledgeable about the plants and animals found along the trails. Exhibits on the use of plants, traditional tools or weapons, cloths and ornamentation are also possible. A special attraction for tourists would be the traditional singsong dances, that are euphorically practised and performed by villagers. Initially, visitors of the nearby Conference Centre in Bundun could be entertained and guided by Gurakor villagers, later their own accommodation units for environmentally conscious travellers could be built of traditional materials and design. Gurakor women already have good experience with the provision of food and service for guests as they periodically work at the Conference Centre in Bundun so they should be able to initiate their own small project with additional training and advice.

5.4 Further socio-economic and cultural considerations

It has to be kept in mind that a farming system not only has to meet the material needs which are sufficiently incorporated in interventions described above, it is also a way of life. Some traditions like slashing and burning mature forests, living in periodical shelters to prepare and plant a garden which is far away from the settlement, traditional division of labour, etc. may be changed with the cultivation system, whereas others like taboos traditional plant use, etc. can still be traded and are explicitly incorporated in the changed AFS.

Land tenure and other legal aspects

Whether the traditional land tenure system can and should remain as it is at the moment has to be discussed and solved among the landowners themselves, certainly with governmental or other advice and help. Thereby the following aspects should be kept in mind:

AF depends to a large extent on the land-tenure system and on people's rights to plant trees. As explained in chap. 2.3.3, the present system is generally in favour of planting perennial crops for individual use. In addition to the perceived ecological and economic benefits of including trees on their farmlands, the farmers enjoy the added advantage of being able to indefinitely prolong their tenure over that piece of clan land for the duration of the perennial crops. In this case, the clan-type land tenure like in Gurakor favours and encourages agroforestry practice.

The opposite situation could arise if women or settlers only occupy land on a semi-legal basis, when land is only lent to them. In such cases, whereby they are often not given formal recognition or reliable assurance that they will be the ones who will benefit ultimately, the long term investment in tree-growing and engagement in improving 'their' land is very unlikely. Other problems like land fragmentation, and uncertainties in land use rights, as long as they are only passed by word, may only be solved if there are at least clear land titles and a more equal and

efficient distribution of land. This can not only help to enable more permanent cropping in close vicinity to the different settlements, it will also prevent conflicts with increasing population pressure. However, local farmers in Gurakor will not lightly enter into long-term arrangements and legally binding demarcation from which the benefits are vague or inadequately guaranteed. Thus farmers and land holders should be assisted to make such arrangements for longer terms and to implement equal rights and therefore direct access for women.

5.5 Instruments for the implementation of a sustainable and appropriate agroforestry

For the implementation of the interventions for sustainable AF on site, different external services have to be provided to promote human capacity building, to organize self-help activities and to strengthen the possibility of their own development. Further, marketing problems have to be solved. Experiences in Gurakor and PNG are the basis for the following postulations for general improvements in the support system for rural agroforestry in PNG.

5.5.1 Development of human resources

The descriptions of indigenous sustainable land use strategies in Gurakor illustrated the depth of knowledge and sophistication associated with the use of trees and technologies applied in shifting cultivation and the farmers' understanding of the impacts on their household system. Although farmers in Gurakor can greatly contribute to development and their traditional knowledge must be incorporated in a improved system, they lack the scientific training and know-how to develop new techniques by themselves to meet the present and future problems. To make the interventions possible, there will have to be a change in some of the farmers' attitudes and habits which can only be achieved through public awareness programmes, training and education of villagers and young people. Therefore it is important to create possibilities for projects, campaigns, courses and other events on the one hand and long term institutionalized but flexible structures and support systems on the other hand.

Improving management, decision-making and entrepreneurship

As deficient management is a major constraint on development in Gurakor, more skilful and responsible managers are required. This will need many changes, particularly in the socio-economic domain like prime commitment to family or clan but not to community as a whole, or habitual hiring of friends and relatives, rather than the best person for the job. This does not mean that Gurakor's farmers or PNG citizens in general should adapt an European, American or Japanese approach but a mixture of traditional values and some concepts borrowed from other cultures might be appropriate. There is no correct answer yet what would be the right management style, and it requires more research or experimentation, but it is known that improving decision-making, entrepreneurship and management largely depends on increasing awareness, education and training as explained in chap. 2.3.4. Thus, training in business management and public

awareness have to be an integral part of sustainable AF development to avoid unrealistic dreams (cf. chap. 2.3.5). Market structures also have to be conductive to the emergence of indigenous enterprise and small businesses should be assisted more. Improving communications and reducing corruption should enjoy increased attention as a development intervention. This includes organizing and structuring the community in such a way that they are more in a position to discuss their problems, find solutions, and put them into practice. Better management includes also alleviating women's load through better division of labour between the sexes and improving women's personal incomes.

Retaining labour in rural areas

Labour must be retained in rural areas if agricultural productivity is to increase and to stem further urbanization and crime. With the possibility of securing a livelihood in rural areas, labour would remain there and augment the very low technology that households in Gurakor apply. Labour availability would help curtail overcropping and consequently degradation of soils.

Appropriate village based education and extension services

Different projects, integrated extension services, training and formal education on a local and regional level should not only exist parallelly, but should be linked up and intercommunicate.

Reform of education

Local governments have to act quickly in developing curricula on all levels from primary school to university that will reflect the local situations and AF as the most important productive sector in rural areas of PNG. New forms of education have to be established, since the present education system does not meet rural development needs and there is invariably a shortage of practical training in the education establishments (cf. chap. 2.3.8). Agricultural or AF education and training establishments should always have a well-run demonstration and/ or experimental farm[62] and it is necessary that students, technicians, and farmers cooperate in applied activities. Two-way communication should enhance the understanding of problems at different levels in the AF sector and the strength of a farmer is a major aspect which should be built upon in any attempt to improve the system. Only then will it be possible to implement meaningful and feasible AF development.

Methods of training and advice should include:

- A training and visit system of individual farmers,
- exhibitions or shows concerning agroforestry,
- appropriate field activities and/or excursions to successful experiences of others,
- education in schools or farmer organizations,
- distribution of innovations and lost traditional knowledge and
- use of audio-visual methods.

[62] If there is some farm, it is often not well run, it lacks qualified personnel and essential training aids.

Improvements of extension services and support or training for self-help initiatives

The methods explained above must particularly be part of national extension services not only in theory! When pre-packaged AF technologies are explained, that are often set off by the general pattern of life and economy and are by their nature alien, and their introduction is usually part of a short-term project, the project often falls apart when the project staff departs. Within the population that is already practising AF experimentalists are legionary. Therefore comprehensive improvements would be necessary, and more varied services should be placed at people's disposal. Extension workers should be better educated in agroforestry, mixed farming and in ideas about the broad integration of protection and production instead of plantation economy and short term increases in productivity. Further on they must be able to visit villages and provide in-situ training, developing with the farmers themselves technologies suited to the users and the ecosystem.

Women, as the main workforce in agriculture, should be given as many educational opportunities as men and there should be more female extension workers to ensure that female farmers will have access to extension work.

Improvement in 'project approaches'

One of the main reasons why projects collapse so frequently in PNG is that their original purpose has been distorted; the original goals have been lost and often people try to get what 'cargo' they could get out of each project, let it collapse, and then try to attract another project in the area. When people think about projects they only think about its objectives as long as the project lasts, so that they do not lead to sustainable activities. Thus the intention of projects has to be to provide capacity and not products and they should last long enough just to teach people new skills or bring in new ideas, after that the project should end. Particular emphasis must be placed upon making people responsible and getting them to freely participate in the transformation of the farming system and sustainable management of the environment in their own grass-roots initiatives, so that after the project ends, people should ideally adopt the ideas they learned through the project, and apply skills, so that they continue to carry on activities on their own without any further outside assistance. Only if people are motivated to do so because they see the long-term payoffs from managing their resources, it will be in a sustainable way. Therefore any activity being proposed has to fit right into community needs, so that people are motivated to do so.

Use other forms of education

As with extension education, so, too, could agroforestry be promoted, documented and publicized by other forms of education. Multimedia public programmes especially on radio and in newspapers should be developed in the vernacular local language, to stress the long-term value of existing AFSs and the dangers of deforestation and agrodeforestation. Courses, workshops and seminars for special groups (e.g. geamsau= women´s club) not only about farming practices but also about the nutritional value of tree foods and traditional medicines should be incorporated, for instance, into childcare information. 'Question & Answer' services could support the agroforestry sector, too.

5.5.2 Improving marketing

Markets for more diversified AF products have to be secured and transporting on the village level needs more structure and planning. Particularly food production for domestic markets and the informal sector must be given greater attention and so must the financing of local businesses through providing venture capital funds to establish equity.

Rural based cooperatives

Although the set-up of farmer cooperatives often suffers from many inherent weaknesses, such as possibility of corruption, high overheads management by rather incapable staff, etc., on the whole it seems to be suitable to improve storage, processing and marketing of AF- products, provided that there are enough qualified managers to run the cooperative, and as long as there is a good government or NGO support (credit, supervision, training, etc.). Existing structures like women's organizations, other existing clubs and social groups could be used as an effective basis for such cooperatives.

Marketing of AF-products

Marketing promotion of local AF products and non-timber products of forests, artefacts and local handicraft must be promoted and diversified, because inadequate marketing including transactions between buyers and sellers, storage, transport, processing, packaging and advertising are a major constraint. Such marketing may in part be undertaken by state-run organizations or marketing boards, through formal cooperatives, via informal associations, or through private channels. Still, cooperatives and state-owned marketing bodies have often proved inefficient, middlemen do usually exploit the ignorance or powerlessness of poor farmers to their own advantage and also informal channels offer a hope of improvement only in limited circumstances (cf. BEETS 1990, 584p). Thus, an important key to this whole issue is to improve the bargaining power of smallholders who, still have little leverage in the commercial market and are quite isolated from information of trading centres. This means that self-help promotion to improve local infrastructure and marketing and communication of project experiences in other areas are important features. There has to be improved access to more independent information on markets and prices (e.g. in radio programmes or newspapers), besides many other measures and mechanisms on a regional or national scale which cannot be further discussed in the scope of this study.

5.6 Present possibilities for implementing interventions

5.6.1 Governmental programmes with main emphasis on cash cropping

An Integrated Development Project, funded by PNG and the Australian Agency for International Development (=Aus AID), was designed to improve the living standard of local communities by introducing alternative ways of using local resources, like sustainable forest management practices, rehabilitating smallholdings in promoting a range of cash crops. Since 1993, the project conducted research and extension on the indigenous galip-nut tree, which is also common in

Gurakor, including the establishment of a processing centre and the production and marketing of dried and salted nuts on a trial basis starting in West New Britain. Besides, the programme involves improving primary health care in the local communities, enhancing the planning capacity of the District Government, encouraging community participation and improving the role and status of women. (ANONYMOUS-E.E. 1997). According to CLARKE, THAMAN (1993, 173), smallholder passion-fruit production, often as an intercrop, and a small vanilla programme, has been promoted in PNG as part of agricultural diversification programmes, but market availability has been inconsistent. Practical implementation of such governmental programmes that are restricted to commercial cash cropping, however seems to be restricted to scanty projects and at least have not reached the study area's region. A initially promising Subsistence Agricultural Improvement Programme of the 80ies has disappear in political infighting and has also not reached the study area.

A special breeding and marketing concept to catch, keep and sell insects (and crocodiles) on a small scale is provided by the Wau and Bulolo Butterfly Ranch through the Department of Primary Industries[63]. On those insect ranches caterpillars (esp. of birdwing butterflies) are fed with planted pasture species. One half of the pupae is allowed to hatch and restock the forest again, whereas the other half of the pupae is collected and the newly hatched butterflies are prepared and sent to the Insect farming and Trading Agency[64] in Bulolo. Likewise other insects like large praying mantises, etc. are kept for preparation and marketing.

5.6.2 Non-governmental organizations and joint ventures of institutions

There are some positive signs in PNG that awareness of the need to address the institutional constraints to real problem-solving is increasing. As a result also in PNG some non-governmental organizations (=NGO), joint ventures of different institutions and initiatives which focus on environmental issues and villager's needs have formed in recent years. The following examples show existing possibilities particularly in the Morobe Province that promote and cover aspects of sustainable resource use and could be helpful in the implementation of AF interventions and human resource development in Gurakor.

Liklik Buk Information Centre (=LLBIC)

The LLBIC, in English, 'The Small Book Information Centre', is an accumulation and disseminating point of information for appropriate development and for increasing awareness. E.g. it publishes and distributes publications in the linking PNG Pidgin English and English that cover themes of agriculture, AF, fishing, food processing, nutrition and health besides various other

[63] This formerly programme of the Office of Environment and Conservation was transferred to the Dep. of Primary Industries as an effect of the 1982 budget proposal on the programmes of the first institution, which at the same time brought about the discontinuation of many useful programmes (cf. GOELTEN 1990, 219).

[64] Only this agency is allowed to export animals to overseas markets.

(ELC-PNG) initially provided training for motivators in agricultural improvements and since 1986 it has developed a more effective decentralized concept of 'Wokabaut Skuls' (= mobile schools). Now the project not only provides education for motivators it further supports direct training in a given village to improve established farmer's livelihood, self sufficiency and health particularly through agricultural improvements and fish projects. The precondition is that the community that applies for such training must built not only a house for the motivator it must also provide teaching rooms and garden plots.

Some further non-governmental organizations

A religious organization that is also present in the Morobe province with the **Adventist Development and Release Association (=AIDRA)**, provides another programme to distribute drought resistant and fast growing plant material and to support the establishment of water supplies (talks with BERGMANN). Information about further activities of this organization were not available.

There further exist other NGOs in PNG with similar aims to those mentioned above which, however, concentrate their work in other provinces:

- The **Christensen Research Institute**[66] (=CRI) which regularly distributes interesting leaflets for community-based sustainable development and has supported and initiated self-help initiatives around Madang, the
- **Individual and Community Rights Advocacy Forum** (=ICRAF) that supports villagers in their land use rights and equal rights for genders in Port Moresby, the
- **Fresh Produce Development Co. Pty. Ltd.** with head office in Mount Hagen, that assists women and men in PNG to develop a competitive and sustainable fruit and vegetable industry.

5.6.3 Constraints of NGOs for implementation of agroforestry in Gurakor

As means of such organizations are restricted they can at the moment not provide help for a larger proportion of PNG's communities. For example the certainly oldest (at least since 1973) and most established 'Yangpela didiman programm' managed to hold 17 'Wokabout Skuls' in PNG between 1988 and 1993 (none of them in the Mumeng district), which is a drop in the ocean of PNG's villages. Other NGOs seem to be even more restricted and often concentrate their work around a particular district or even few singular projects. As a consequence most villagers in Gurakor even have not heard of such organizations and their services. So how can they apply for their help. Moreover preconditions for the application often afford high levels of motivation in advance not only of single households or clans but often the whole community e.g. to build houses. This is in the case of Gurakor and certainly many other villages in PNG an illusion. If the village would really apply for assistance it will be poor chance or they will get the aid

[66] The latest news is that this very engaged organization had to declare itself bankrupt (ENGELBERG 1998, correspondence)

through knowing the right people.

Further, there are inherent problems within strategies of some current NGOs in PNG that concentrate on 'sustainable' resource use, which does usually not include AF improvements, but the prevention of large-scale logging. On the one hand it is a positive sign that they offer people an alternative through small-scale timber extraction with portable sawmills on the village base against destructive commercial large-scale logging[67]. However, environmental groups competing against commercial loggers often showed villagers that sustainable use of timber is better for them by putting money into people's hands for the higher valued 'ecotimber'. This strategy again leads to the result that there is not conviction towards any goal apart from making money and further to base decisions on the basis of money instead of long term gains. Such an attitude will certainly not ensure sustainable development in the future, since it is not competitive. This example shows that, although economic incentives are timely and appropriate (likewise in ecotourism, butterfly ranching and galip nut marketing), they cannot be developed in isolation! Bringing about awareness alone cannot lead to sustainable use, comprehensive education as a mechanism to change people's views in contemporary land use must build conviction.

5.6.4 The conference centre and local training centre for rural development

Asples Trening Senta (=ATS)

As a consequence of lacking alternatives of development for the rural poor and particularly non-established drop-outs, members of 10 villages in the Mumeng council area developed the idea local training centres for village development. It was already mentioned in the foreword of this paper how the present ATS in Bundun emerged. ATS now provides the most appropriate and closest facility for training young people also of Gurakor primarily directed towards sustainable and appropriate farming practices, management and entrepreneurship.

Participation and integration of traditional knowledge

As the pilot project in Bundun was the idea and initiative of the rural population itself, that has ongoing participation, it is safeguarded that its programme fully integrates villagers needs and is appropriate to the local situation. A cadre of community leaders was built to implement the project and two instructors from surrounding villages developed the curriculum with the assistance of Dr. U. Bergmann form the HDC, who assists with training, advice and supervision for the instructors. In 1996 members of the communities and prospective trainees of the 10 villages renovated buildings of a defunct school and planted initial gardens on leased land of the ELC-PNG in Bundun. Parents are involved in ongoing participation, as they allocate land to the trainees, assist them with the setting up of their farm and nominate board members of management that are responsible for the overall project, finances, etc (cf. BERGMANN 1997, unpub.).

[67] The environmental friendliness of the portable sawmill projects is largely caused through default, and not by design because afforestation is rare and villagers themselves violate guidelines they accuse the commercial loggers of ignoring.

The project and its curriculum is still at a testing stage and other villagers' individual problems or ideas, as described in this paper, might well be included. As it was traditionally practised in the villages before, some village elders or specialist resource users should be included as temporal lecturers and experts to teach young people about traditional ways of interacting with the natural environment or uses of traditional medicine, food or materials. This would help to mitigate the rapid disappearance of diversified traditional knowledge of each village and link it with the sound improvements towards more efficient resource use.

The programme

The programme of the pilot project started in June 1996 with the first trainees graduating at the end of 1997. It is built on the philosophy of 'Teach by showing, learn by doing'. After the first course and practical training at the centre, the trainees go back to their villages to implement the acquired skills in their individual farms or plots and later proceed training at ATS, going back and forth for several times until they will finally finish with a test and take domesticated rabbits (that were only introduced to PNG in 1993), pigs or other livestock to their village. Not only will the trainees experience some new agricultural methods, also parents and other village members take part and go through the learning process (cf. BERGMANN 1997, unpub.). It would go too far to describe the extensive contents of the course, but it is clear that pupils will not only be educated and trained in mixed farming practices, they will also gain education in ethics, nutrition, health, basic marketing, bookkeeping, building skills, they will learn to work regularly and to follow a set routine, which is important for keeping livestock and earning regular income.

Distribution of plant material/livestock and other inputs

The experimental farm in Bundun (ATS+HDC) provides a good possibility to promote and distribute healthy and well adapted plants and animals not only to the trainees but also to other farmers. As experienced during this study people are fascinated by plants, like to experiment with them, and will happily carry a young individual plant for long distances to establish it in a new home. If it works there, it will be produced and further disseminated. It makes sense, therefore, that at least some of the attempts at agroforestry intervention concentrate simply on supplying trees and other seed or plant material for distribution, so that further experimentation can also be carried on locally. Some of these trees may be traditional, some newly introduced, as long as they prove not to be invasive, like Guava and some introduced legumes (cf. app. 3). This is likely to be a very effective intervention in achieving the goal of encouraging AF. Likewise livestock or necessary inputs can and are distributed at ATS e.g. for the manufacture of stables, which, however, must generally be accompanied with training.

Aside from regular exchange of experience in breeding of rabbits with the Department of Agriculture and Livestock, Unitech Lae there is however not much scientific assistance concerning sustainable AF improvements, so that this thesis might help to add some aspects to the experiences of organic farming in the Centre described below.

Human Development Centre Bundun (=HDC)

The HDC with its conference facilities adjacent to the pilot project ATS in Bundun additionally provides the venue for planning seminars as the 'Law and Order Awareness Seminars' and 'Youth development Seminars' that brought about the idea of ATS and training courses for instructors or villagers. Further people who do not want to attend the whole training, but learn about improved crop husbandry, physical or other methods or soil improvement with or without the integration of livestock, or special groups like the Women's Club could take part in courses or seminars in the HDC. The practice of permanent organic farming at the HDC since 1982 years, and later at ATS, provides a strong locally based framework and example for sound management and incremental agro-ecological innovation. This example can serve to convince farmers that the innovations proposed are good and well proven. Therefore it is very important that all plots or at least a demonstration and experimental farm (at the moment particularly valid for a 0,3 ha home garden for the subsistence of a family that has participated in the Centre since its initiation) are very well managed, otherwise visitors are sceptical about adopting such innovations.

5.7 *Concluding remarks to the role of the government in contributing to sustainable agroforestry development*

At least in the long term it must be part of governmental education and training to contribute to human resource and sustainable agroforestry development instead of just leaving the whole issue to NGOs and self-help groups. It has also been recommended on the 21st Waigani Seminar in 1993, where the National Sustainable Development Strategies were developed (cf. chap.1.2.2), that government must make greater efforts to introduce environmental education into the school curriculum educate representatives at the grass roots level etc. However, the few attempts to reform the present school system, curricula and governmental training services proved to be very unlikely or at least slow and there is still a lack of practical training facilities and a shortage of qualified teachers who can initiate and play leading roles in promoting environmental and AF education or raising awareness.

As long as agriculture and forestry fall under different ministries[68], it will be hard to combine the separate training, education and research institutions; separate extension services that give advice to land users. The basic institutional structures like agronomists or foresters or even development agents are generally geared to short term maximisation of individual components, be they food crops, cash crops, animals or trees and rather focus on optimization of whole landscapes. There is little understanding that the land-user needs to share out his resources for the production of other commodities or services. Additionally, the inability of technical experts and institutions to

[68] When the Australian colonial power established its administrations in PNG, the institutional structures, policies and aims related to land use and development were simply copied from Australia, and the model has been continued after independence.

understand how social, religious, cultural and traditional beliefs and preferences can nullify a convincing cost/benefit analysis has been shown in many failed development projects. It is, quite obviously, this lack of understanding of the complexities of the land use system and lacking interdisciplinary analysis of constraints and potentials in conventional institutions that is the basic cause of the many failures and frustrations in trying to solve the land-use problems.

Thus in the short and in the medium term, and within existing institutional structures, collaborative programmes which cut across disciplinary boundaries and address concrete land-use problems must be encouraged and given more support, both at the national level and at the level of international agencies such as donors, UN bodies, and International Agricultural Research Centres, as even most international bodies and institutions are still entrenched in disciplinary thinking and actions.

Interdisciplinary thinking should not remain a domain of environmental programmes like the PNG Biodiversity and Resource Management Programme for the development of Wildlife Management Areas together with the communities. This recently developed truly participatory way in resource management is still at a testing stage and only applied in special cases as an alternative to establishing National Parks (cf. app. 6).

5.8 Two scenarios

The following two different szenarios shall visualize an image of the future landscape and a imaginary famely's life in Gurakor some 20 or 30 years behind. Szenario 2 may help residents and decision makers to become aware of current processes of deforestation and overuse of land occurring in their area, whereas szenario 1 shows a more desirable future image ensured through appropriate and sustainable agroforestry interventions and ideas for improved land. To show the severity of these scenarios two real pictures that were taken in June 1997 in PNG are added. The first one shows the still remaining forested mountains around Gurakor with the main settlement in the middle of the picture, whereas the second one shows a totally deforested landscape in the Ramu valley in the same province.

5.8.1 Szenario of sustainable agroforestry development

People are well educated and the population density only slighly increased. The farming family in fig. 35 like most others in Gurakor manage to maintain and to develop their resources in a sustainable way. Diversified regional and to some extend export cash crop production has become a substancial part of the farming system as well as processing of food and non-timber forests products in local cooperatives. Livestock farming is an integral part of the system. A destinction is made in the landscape between public and privately owned land. Whereas land under cultivation is privately owned, remaining forests on steep slopes and main public water reservoirs, public paths and culturally important places remain common good and their benefits are shared. Public works are done by self-help groups. There is a governmental aid post which is

constantly supplied by a small farmer cooperative in Gurakor who have specialized on cultivation and processing of a variety useful medical plants, and also other hospitals and aid posts in the region recognized the value of the indigenous medical system and have not wholly reverted to and relied upon an imported, modern one. Gurakor is often visited by backpackers from overseas who are welcomed by traditional 'singsongs'. They enjoy the exceptional beauty of the landscape, the guided tours through Gurakors rainforests and mixed gardens, appreciate locally manufactured goods the local food which is very diversified and creatively prepared.

The village Gurakor has managed to remain a self-guided and independent community since they have recognized the importance of cooperation and long term effects on economy, culture and environment.

5.8.2 Scenario of overexploitation and degradation

The population has significantly increased. The family living in the smaller house with 6 children does not have sufficient land to feed themselves anymore. Only some fertile pieces of land a 4 hours walk away are available. Due to unsustainable land use for short term maximization of yields without fertilization almost all arable land in Gurakor has been degraded over the last 20 years and converted to stabilized Imperata grassland. Rapid deforestation of steeplands to expand cultivated land and agrodeforestation to give way to monocropping of few marketable products has let to irreversible degradation, massive soil erosion, pest infestation and almost complete breakdown of the ecosystem. Without proper education the children therefore left Gurakor, but only two of them could find a job in Lae city and are irregularly supporting the rest of the family.

A neighbouring widow with her 8 children in close vicinity was given a special credit to built up a broiler farm as she had no right for land. Since her husband was killed in an inter-clan fight the family's cultivated land was occupied by the first born brother of him. Since prices of introduced chicken fodder have enormously rised with the inflation and economic crises in PNG, she recently had to sell all broilers and give up the project before she could pay back the credit. She and her children have no perspective in Gurakor anymore and may also leave to search for work in town.

Wells had to be drilled since surface waters in Gurakor are spoiled, siltated, and regularly drying out during dry seasons. Most children and adolescents constantly suffer under malnutrition whereas many storekeepers and other business people are overweight and get typical chronic diseases of the consumer society.

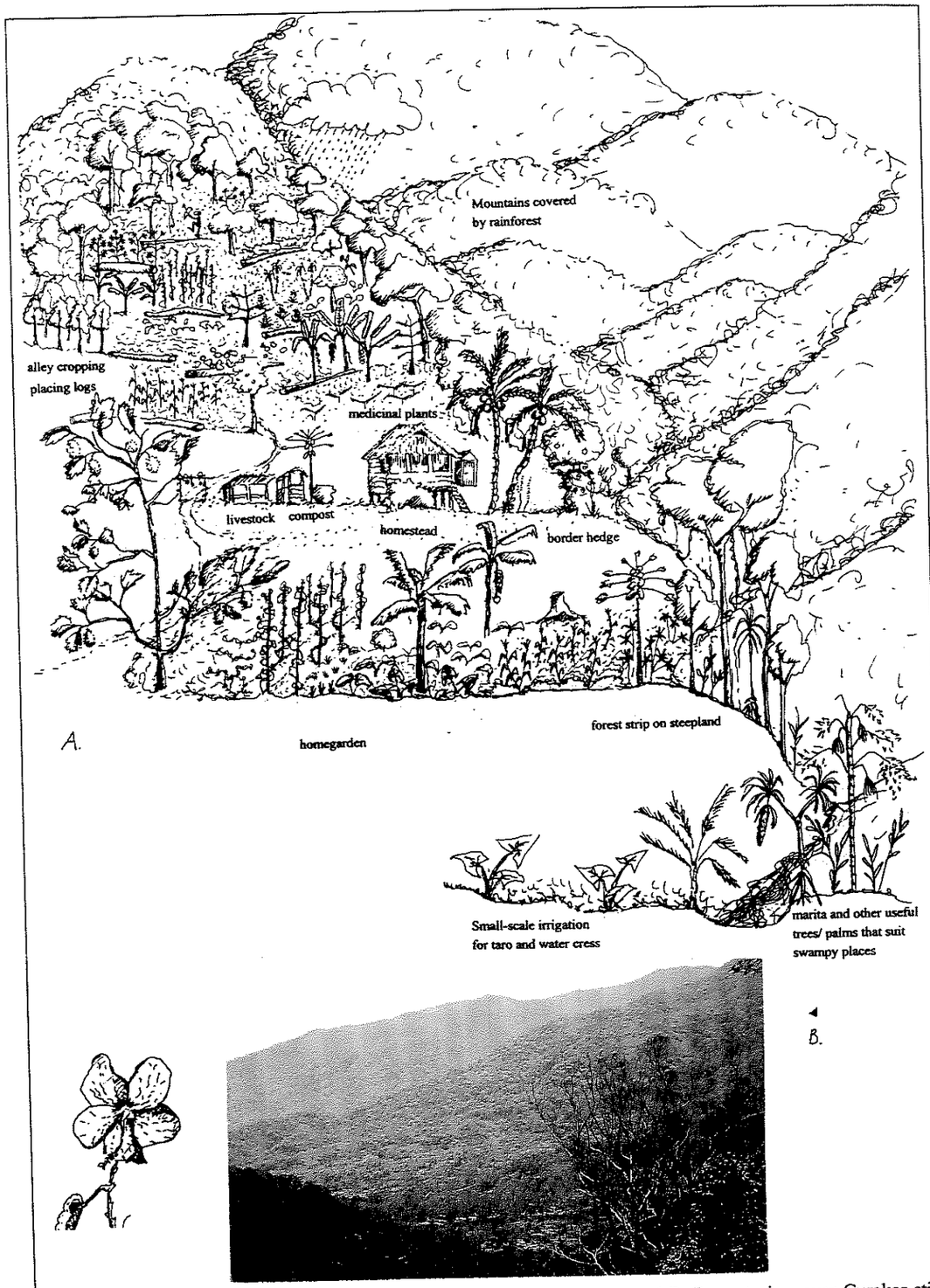
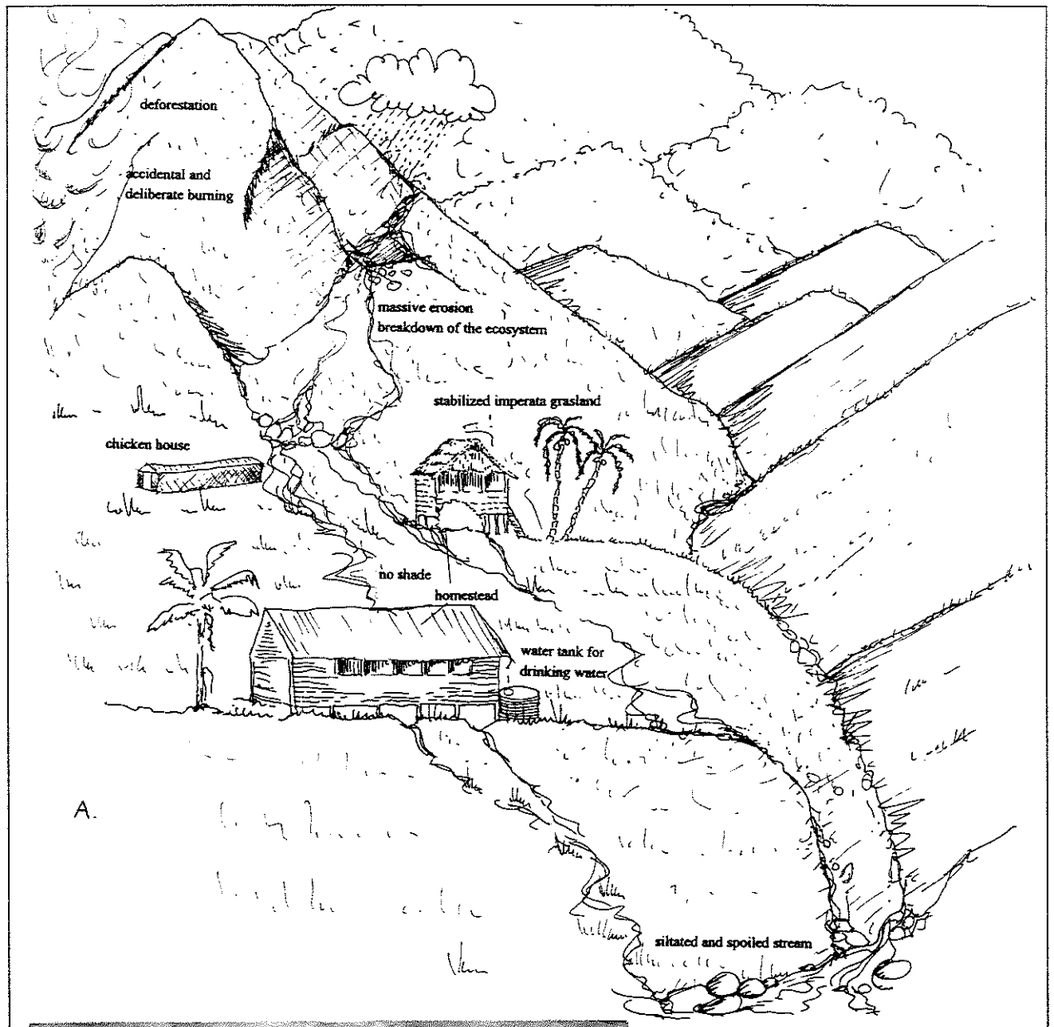


Fig. 36: A: Scenario of sustainable agroforestry development in Gurakor and B: Present view over Gurakor still surrounded by forested mountains, 1997.



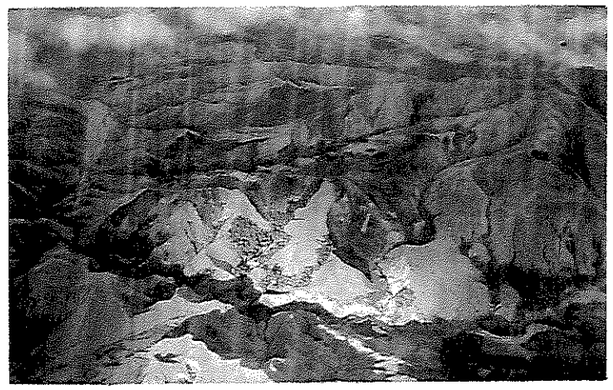


Fig. 37: A: Scenario of overexploitation and degradation and B: Real view over the deforested landscape in the Ramu valley, PNG 1997.

6 SUMMARY AND CONCLUSION

This study's description about appropriate and sustainable agroforestry development for farmers in the village Gurakor, PNG, may at times have seemed very detailed but the coverage of the topic remains far from complete. This is due to the complex nature of sustainable development strategies and because the planning for improved farming practices in very diversified tropical agroforestry systems appropriate to subsistence farmers' needs, must consider a number of issues. Therefore economic, ecological and socio-cultural aspects have been included in this study. A pragmatic and objectives-oriented approach during field studies in close collaboration with local farmers in Gurakor, as well as for the evaluation, was chosen to allow cost and time-effective planning in spite of the lacking data base. Aims for sustainable agroforestry that also served to evaluate the present system were derived from international and national conventions, particularly the different Rio documents Agenda 21, CBD, CCC, FP, RDED, PNG's National Sustainable Development Strategies and its Constitution.

The examination of farmers' needs and problems in the village Gurakor served to find viable ways to integrate conservation needs and development on a local scale. Further the assessment of strengths and weaknesses of the natural circumstances and present farming practices were necessary to put improvements in agroforestry on a realistic and effective basis.

There are constraints especially due to the limited natural production potential of the soils under tropical climate conditions and due to limited knowledge of the farmers to meet newly emerging problems which have been caused by population pressure and contact with western civilization.

The immense diversity of biological resources in virgin and old-grown secondary forests as well as on shifting arable and fallow land present manifold values that have to be promoted, tapped and conserved. Furthermore, the great knowledge of Gurakor's farmers to manage these resources is highly valuable and therefore was incorporated in the concept for improvements of the system. The documentation of the indigenous system in Gurakor showed that there is nothing new about multi-storey cropping, known as agroforestry, even though it has often been suggested to smallholders as an innovative technique they might adopt. In fact the native system has always involved trees as components as they have played and should continue to play a significant role in the provision of useful materials and other needs, in the enhancement of productivity, diversity, and stability of the agroecosystem. The shifting cultivation system, however, which used to be very sound ecologically under conditions of abundant land, is under a serious threat from population pressure and land scarcity causing imbalance.

Detailed appropriate interventions have been developed which allow farmers to sustain and increase productivity to satisfy their basic needs without compromising the future concerns.

Many possibilities do exist and have been tested in other areas and countries like improved crop husbandry, measures for erosion control, diversification and intensification techniques and more

effective plant nutrition under the use of local resources. To maintain a healthy landscape it is not necessary that every landholding, every stretch of land, contain trees, just as every farmer need to be an agroforester - but it is necessary that there be sufficient trees in the right places, at least on slopes and along streams. Other strategies to ensure better self sufficiency and improved standards of living are in the field of better storage, processing, management, marketing and non-farm employment.

Thereby it has to be kept in mind that within the bigger picture of PNG's history, the influence of outsiders is very small and recent and it must be the main objective in PNG AF development to maintain or recapture self-reliance and self-determined way of live. Sustainability has to be practised out of farmers' own motivation and conviction, as their response to programmes and projects is only likely to be sustainable if they are genuinely involved in their design and implementation and fully recognize the real aims and chances of sustainable development. Thus the key role and most important factor in sustainable agroforestry is the development of human resources through the participation of villagers, training, improved information and integrated decision making. Therefore reforms in existing structures are necessary and existing alternatives of NGOs must be tapped. Further small farmers will only change some of their farming practices and current uses of the resource base if they have the appropriate economic incentives to do so. This means that sustainable AF development cannot be pursued in isolation, but management and marketing have to be improved to the benefit of farmers.

Some aspects and possibilities of already existing supportive structures have been shown in this study and criticism has been made. As governmental services have failed as the past has shown and because non-governmental organizations are often out of 'reach' for local farmers the conclusion has been made that the most promising change for subsistence farmers in Gurakor today lies in the nearby Training Centre for Rural Development. This self-help initiative of local farmers and the adjacent Human Development Centre Bundun was the starting point of this thesis and together with Ulrich Bergmann, director of the latter centre the idea to write this paper was developed.

The author hopes that this thesis may contribute to the recognition, support and wider dissemination of the Local Training Centres also in other regions, in the effort to stem agrodeforestation and to stimulate the future thriving of PNG agroforestry on the basis of the rich indigenous resources that has already for so long successfully blended production with protection.

The interesting conclusion for the author herself was, that planning in a developing country, but to a certain extent also in western countries, shows that methods that are based on schematic and scientifically recognized regularity are often inappropriate due to lacking data bases and means to produce the necessary results. The best example may be the PNG Resource Information System which was certainly developed with an immense expenditure but did in many cases

provide misleading base data and evaluations for the planning unit. Experiences during the course of this study showed that for example yield measurements in mixed cropping systems under the influence of environmental and also human (theft and sabotage) hazards or just under the irregular patterns of harvesting are hardly possible in a rural village with subsistence farmers. Therefore calculative models were not formally included in the sequence of procedures, they were nevertheless employed in a few stages of evaluation.

Moreover planning in a different culture afforded to be particularly aware of peoples' points of views and beliefs which can nullify logical western strategies as many projects in PNG have already shown. Thus, the local scale-level was found as most appropriate because of the complexity of agroforestry and PNG's cultures and to integrate local knowledge and wishes with regional and international aims concerning sustainable land use. Due to lacking written information for this study area most data were best available through local farmers.

Moreover land evaluation and landscape planning methods that concentrate on the land and not its users were not refined enough to address the large diversity of PNG production systems, needs and aims of sustainable development. Thus an integrated approach was applied which can best be compared with the strategy known as 'Diagnosis and Design' method (cf. RAINTREE 1990, 33 pp), a follow up product of farming systems research for diagnosis of land use problems and designs of AF solutions. This method seeks to achieve an appropriate design, allows more complex issues to be dealt with on different planning levels, is as participative as much as the planning level and stage requires and is an open ended process.

There are still many research gaps to be filled as it was sometimes mentioned in the text. Particularly the wide range of species and their potential uses remain in many cases unused and unknown. More efforts should be made to assess details about indigenous nitrogen fixing tree species to avoid further dissemination of introduced often invasive species, about medicinal plants, or game farming, just to mention some fields of interest. Experiments with new AF technologies and their effectivity are lacking in PNG apart from the cash crop sector. Those as well as better breeding and dissemination of plant material and seed, particularly of traditional crops, must be developed decentralized in rural areas.

According to the ambitious National Sustainable Development Strategies (cf. chap 1.2.2) and PNG's Constitution which declares its 4th goal to be for PNG's natural resources and environment to be conserved and used for the collective of future generations, all people involved and interested in the development of this country should do their part in preventing further destruction of the environment. This certainly requires strong levels of motivation and a great deal of work to sensitise the community to the fundamentals of sustainable development not only in Gurakor.

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APPENDIX

Appendix 1: Different methods of interviews

Different methods of interviews were applied:

Through initially ***open-ended interviews,*** guided by intuition and experiment but with the main goals in mind, I was able to develop a sense of what needed to be asked in more structured interviews. As people began to learn what interested me, discussions drifted more and more to my field of interest.

Such interviews were often in the form of ***walking interviews*** with individuals or groups of the three clans to discuss the landscape, land uses, and activities in the different territories. As I walked in the forest, worked in the field or went hunting with the local people, they naturally talked about their perceptions of their environment around them. They also showed me medical herbs in their home gardens and fruits from the forest.

After having identified key-persons, I made further ***individual interviews*** focusing on specialized knowledge and skills or discussion. Traditional knowledge of old land use practices, the traditional use of medical plants and the history of the settlement in particular could only be provided by village elders.

For such special themes I prepared a checklist of topics and questions that I wanted to cover, known as ***semi-structured*** interviews. Some questions were determined beforehand and others arose during the course of the conversation. As the discussion got under way new lines of inquiry arose naturally and I let some of my prepared questions fall to the wayside, left for a future discussion.

This guideline for information gathering was focused on AF, socio-economy and culture, but tried to remain open to the farmers' ideas. Each evening a summary was written and often discussed again with other villagers.

The **socio-cultural** topics included:

- land (ownership, usage rights)
- roles of different genders
- labour (input) farm size
- identification of formal community organization (leaders, clans) and informal social structure (land-user groups)
- important traditions and beliefs
- level of education, skills and knowledge
- degree of openness to innovation
- community needs, problems and potential solutions.

Mayor **agronomic aspects** and **natural site conditions** covered were:

- climatic situation, water availability and quality, soil types and their quality,

- present crops and varieties, fallow vegetation, useful plants and wildlife, problems with invaders/ weeds, etc.,
- land-use system and cultivation techniques,
- land-use changes, soil productivity.

Through ***participant observation*** (action interviews) involving working with individuals or small groups, I was not only able to learn from direct experiences about their land-use systems, activities and problems, but also to overcome my feeling of alienation and to gain their trust. I began to take stock of what is different and similar to my own culture. Living with PNG people and sharing with them many facets of their life, from subsistence activities such as cooking, farming, gathering firewood, washing in the river etc. I came to know many elements of everyday reality. In this totally different culture, I strived to be aware of local customs and to respect them. Often it is also important to be aware of those customs when interpreting their statements. In the intimacy of individual interviews also personal information came out. I tried to adopt local ways of speaking and using expressions, words and gestures used locally and that people can readily understand. But still it was not always easy to estimate the opinions and statements of the village people, which are extremely influenced by socio-cultural standards and a, to a certain extent, still animist society.

Appendix 2: Soil and rainfall field data

As investigations were oriented on the German 'Bodenkundliche Kartieranleitung' the following field data are written in German. This examination involved:

- sample number, date and site (elevation, slope, rock outcrops, land use, surface form, bedrock)
- profile description with their horizons and their organic matter status, particle-size class, stones (abundance, size, shape, lithology), colour (moist soil, ped face, air-dry, rubbed and main mottles), soil water state, ped (size, abundance, shape lithology), voids (packing density, porosity class). Consistency (soil strength, ped strength, failure, cementation, stickiness, plasticity), roots (abundance, size), coats, horizon boundary and notation.

Soil researchers also measure the diverse organic and chemical constituents in the soil. However, I was not able to carry out laboratory analyses to discover the relative contents of organic matter, nitrogen, phosphorus, potassium and trace minerals that are required for plant growth or even cation exchange capacity. Only the pH of the soils was tested with the help of pH test stripes provided by Lae Unitech, which however, seemed to be too old, as indicatory colours have always shown the same results. The composition and physical properties give the soil a distinctive colour and consistency which I was able to identify with the 'Munsell Colour Charts'.

2. A. SOIL-PROFILE IN GURAKOR, (field name:) GWA

Aufnahmedatum: 16.07.97	Profil Nr.: 1		Karten Nr.:	Witterungs-ereignis: nachts Regen		Nutzung: 7 jähr. Brache 1992 Ananas + Süßkartoffel Grasbrache, 1997 gebrannt		Reliefposition: W		Gestein: Alluviale Ablagerung mit Quarzsteinbrocken, Opale									
Bearbeiter: M. N.	Rechts Wert: 146° 40'		m ü.NN ~600-700	Ø N: 2800 mm	Ø °C: ~25	Vegetation: Reste v. Ananas + Imperata Gras		Exposition: N-W		Landschaft: Reliktisches Alluvium Granite, Opale									
	Hoch Wert: 6° 50'							Inklination: HF N3											
Standortsaufnahme Im Gelände	Tiefe cm	Bodenart	Kies + Steine Vol.%	Bodenfarbe (frisch)	pH-Wert ($CaCl_2$)	Karbonat-gehalt Gew.%	Humus-gehalt Gew.%	aktuelle Feuchte	pF	Gefügeform	Besonderheiten	Hohl-räume	Gefüge-stabilität	Lagerungs-dichte kg/dm³	Durchwurze-lungsinten-sität	Lagen-grenzen	Horizont-bez.		
	-4	sT	~3	hue 7.5 YR 3/3	6 ?	< 0,5 K	10	frisch	3	Subpolyeder 2-5mm	gleichmäßig	wenig	gering	gering	mittel	fließend	A(h)		
	-28	sT	~4	hue 5 YR 4/4	6 ?	< 0,5 K	6	frisch	3	Subpolyeder 5-10mm	sehr dünner Humushorizont	wenig	gering	mäßig dicht	schwach	fließend	Bt		
	>28	sT	"	hue 5 YR 4/6	6 ?	< 0,5 K	3	frisch	3	Subpolyeder 5-10mm	mit Aschereesten graduelles Profil	wenig	mäßig	sehr schwach	sehr schwach	fließend	C ?		
	Entwicklungstiefe: 50-60 cm			Hauptwurzelraum: von 0 bis 28 cm				Bodenform: eine Art Braunerde				Varietät:							
	Durchwurzelungstiefe: ... cm			akt. Grundwasserstand: ... cm unter GOF				mittl. Grundwassertiefstand: ... cm unter GOF				Humusform: Aschereste							

Bewertung	Mächtigkeit dm	Durchwurzelbarkeit	GPV Vol.%	GPV Bewertung	LK Vol.%	LK Bewertung	nFK (eff. Wurzelraum) Vol.%	nFK (eff. Wurzelraum) Ltr./m²	FK (bis max. 1m) Vol.%	FK (bis max. 1m) Ltr./m²	Kf-Wert cm/Tag	Kf-Wert Bewertung	KAK mval/kg	KAK Bewertung	S-Wert mval/kg	S-Wert val/m²	S-Wert Ah x 1 Sonst.x 0,5	Humus kg/m²	Nt kg/m²	Nv g/m²
		gut	56	hoch	10	mittel	19	-	46		40-300	hoch								
		mittel	40-48	mittel	4-7	gering	12-15	-	36-41		10-40	mittel								
		mittel	"	mittel	4-7	gering	12-15	-	36-41		10-40	mittel								

2. B. SOIL-PROFILE IN GURAKOR,
(fieldname:) LIPAGO

1985 gerodet, kultiviert – 1987 Buschbrache
1990 " " 1992 " 1996 gerodet – Schäden durch hohe Niederschläge

Standortaufnahme Im Gelände

Aufnahmedatum:	Profil Nr.:	Karten Nr.:	Witterungs-ereignis:	Nutzung:	Reliefposition:	Gestein:
16.07.97	2		nachts Regen	gerad neu gerodet 1997	OW	Alluviale Ablagerung, Granitbrocken + Opale
Bearbeiter: U.N.	Rechts Wert: 146° 40'	m ü.NN	Ø N: 2800 Ø °C: 25°C	Vegetation: Piper aduncum, Süßkartoffel, Farne	Exposition: HMG KF W	Landschaft: Reliktisches Alluvium Colluvium (Lehmfluß)
	Hoch Wert: 6° 51'	~ 500			Inklination: N4	

Tiefe cm	Bodenart	Kies + Steine Vol.%	Bodenfarbe (frisch)	pH-Wert ($CaCl_2$)	Karbonatgehalt Gew.%	Humusgehalt Gew.%	aktuelle Feuchte	pF	Gefügeform	Besonderheiten	Hohlräume	Gefügestabilität	Lagerungsdichte kg/dm³	Durchwurzelungsintensität	Lagengrenzen	Horizontbez.
-14	sL	30	hue 7,5 YR 3/4	7	< 0,5	~ 5	trocken-frisch	3-4	Polyeder-2-5 subpolyeder	wenn trocken feiner heller Staub	ja	mittel	gering	sehr stark	fließend	Ah
-30	sL	30	hue 10 YR 4/6	7	< 0,5	~ 2	trocken-frisch	3-4	Krümelgef. 2-5	in Fingerrillen (= Löß)	wenige	mittel	gering-mäßig dicht	mittel-stark	fließend	B(t)
>30	sL	40	hue 7,5 YR 5/8	7	< 0,5	~ 1	frisch	4	Krümelgef. 1-4	sehr guter Süßkartoffelstandort	wenige	mittel	gering	schwach	fließend	C
				Labormessung mit HCl ~5												

Entwicklungstiefe: ~60 cm | Hauptwurzelraum: von 0 bis 20 cm | Bodenform: Eine Art Braunerde | Varietät:
Durchwurzelungstiefe: ~80 cm | akt. Grundwasserstand: . . . cm unter GOF | mittl. Grundwassertiefstand: . . . cm unter GOF | Humusform:

Bewertung

Mächtigkeit dm	Durchwurzelbarkeit	GPV Vol.%	GPV Bewertung	LK Vol.%	LK Bewertung	nFK (eff. Wurzelraum) Vol.%	nFK Ltr./m²	FK (bis max. 1m) Vol.%	FK Ltr./m²	KI-Wert cm/Tag	KI-Wert Bewertung	KAK mval/kg	KAK Bewertung	S-Wert mval/kg	S-Wert val/m²	S-Wert Ah x 1 Sonst.x 0,5	Humus kg/m²	Nt kg/m²	Nv g/m²
	gut	52	hoch	14	hoch	22	–	38	–	100-300	sehr hoch								
	mittel	~50	hoch	12	hoch	20	–	35	–	~40	hoch								
	schlecht	~52	hoch	14	hoch	22	–	38	–	~100	hoch								

2.C SOIL-PROFILE, GURAKOR
(fieldname:) GULGHO NEXT TO THE CEMETERY

Standortaufnahme Im Gelände

Aufnahmedatum:	Profil Nr.:	Karten Nr.:	Witterungs-ereignis:	Nutzung:	Reliefposition:	Gestein:
18.07.97	3		trocken	3 jährige Brache	W	Alluviale Ablagerungen
Bearbeiter: U.N.	Rechts Wert: 146° 40'	m ü.NN	Ø N: 2800 Ø °C: 25	Vegetation: Piper aduncum, Farne, Alpinia spp., Pitpit...	Exposition: W	Landschaft: reliktisches Allurium (Lehmfluß)
	Hoch Wert: 6° 48	~ 300			Inklination: TE N1	

Tiefe cm	Bodenart	Kies + Steine Vol.%	Bodenfarbe (frisch)	pH-Wert ($CaCl_2$)	Karbonatgehalt Gew.%	Humusgehalt Gew.%	aktuelle Feuchte	pF	Gefügeform	Besonderheiten	Hohlräume	Gefügestabilität	Lagerungsdichte kg/dm³	Durchwurzelungsintensität	Lagengrenzen	Horizontbez.
-18	sT	–	hue 7,5 YR 4/3	7	0,5-2	7	frisch	3	Krümelgefüge fein		wenig	gering	gering	mittel	klar	Ah
-58	sL	–	hue 7,5 YR 4/6	6-7	0,5-2	3	frisch-trocken	3-4	Subpolyeder	schwarz-rot marmoriert	wenig	gering	gering-mäßig d.	sehr schwach		WG
-65	sL/lS	–	hue 5 YR 4/6	7	0,5-2	2	frisch-trocken	3-4	Subpolyeder grob	Eisenband? Stauwasser	wenig	mittel	dicht	sehr schwach	Streifen	
65...	lS	–	hue 5 YR 4/4	7	0,5-2	1	trocken	4	"	schwarz-rot marmoriert		gering-mittel	dicht	sehr schwach	fklar	WG

Entwicklungstiefe: ~100 cm | Hauptwurzelraum: von 0 bis 40 cm | Bodenform: – Eine Art vergleyter Boden | Varietät: –
Durchwurzelungstiefe: ~80 cm | akt. Grundwasserstand: k.A. cm unter GOF | mittl. Grundwassertiefstand: . . . cm unter GOF | Humusform: –

Bewertung

Mächtigkeit dm	Durchwurzelbarkeit	GPV Vol.%	GPV Bewertung	LK Vol.%	LK Bewertung	nFK (eff. Wurzelraum) Vol.%	nFK Ltr./m²	FK (bis max. 1m) Vol.%	FK Ltr./m²	KI-Wert cm/Tag	KI-Wert Bewertung	KAK mval/kg	KAK Bewertung	S-Wert mval/kg	S-Wert val/m²	S-Wert Ah x 1 Sonst.x 0,5	Humus kg/m²	Nt kg/m²	Nv g/m²
	gut	56	hoch	10	mittel	19		46		40-300	sehr hoch								
	mittel	48	mittel	13	hoch	19		35		~100	hoch								
	mittel	37	gering	7	mittel-gering	14		30		~10	gering								
	"	"	"	"	"	"		"		"	"								

2.D. MONTHLY AND ANNUAL RAINFALL (MM) PROBABILITY BY PERCENTILES AND QUARTILES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
LOWEST	170	77	112	89	5	12	31	51	81	58	39	69	2172
10	180	160	178	89	68	43	62	110	81	61	124	130	2175
25 L.Q.	250	223	226	205	92	98	122	138	119	86	157	289	2468
30	293	252	233	218	116	100	125	140	134	100	170	308	2717
50 MED.	387	344	297	303	169	115	149	171	188	175	207	362	2805
70	425	375	369	330	229	172	185	188	212	223	261	423	2993
75 U.G.	442	377	392	372	237	176	194	199	237	232	268	428	3018
90	480	397	488	451	307	224	227	237	367	293	308	464	3378
HIGHEST	496	450	589	530	316	229	228	365	452	338	332	606	3420
N°. OF RECORDS	17	17	17	18	18	18	18	18	17	18	18	18	17

(Gurakor station no: 200199 (1952-69) as in KEIG et al. 1975, 59)

2.E. MEAN MONTHLY AND ANNUAL RAINFALL (MM)

YRS. OF RECORD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
17	355	297	317	280	170	128	150	171	200	170	208	346	2803

(Gurakor station no: 200199 (1952-69) as in KEIG et al. 1975, 26)

Appendix 3: Inventory of useful and present plants for agroforesrty in Gurakor

Common name in PNG Pidgin English (English)	Scientific name	Origin, risk of invasion	Wild form/ varieties	Demands to light	Demands to soil	Other demands	Ecological functions	Food value	Other values
A. STAPLE FOOD CROPS (ESP. RHIZOMES, TUBERS AND ROOTS)									
Paragum (Giant taro)	Alocasia macreorrhiza *(L) Schott*	○	⌀	⊙	(① ≅)	$(R)_{1\text{-}1.3m}$	-	t E M	e
Taro tru (Taro)	Colocasia esulenta *(L) Schott*	◎ 2000✓	❖	⊙	(① ≅) ≋ -…	$(R)_{1\text{-}1.3m}$	-	t l E M V (P)	(F) (⊛) (⧖)
Longpela Yam (Longer Yam)	Dioscorea alata	○✓	❖[1]	☼-⊙	③ ⇓	| $R_{0.5\text{-}1.2m}$	✗	t E (P)	⧖
Mami (Common yam)	Dioscorea esculenta *(Lour.) Burkill*	○✓	⌘	⊙	③ ⇓	| $R_{0.8\text{-}1m}$	✗	t E (P)	⧖
Yam (Bitter yam)	Dioscorea hispida+ D. bulbifera *(L.)*	◎✓	❖	☼-⊙	③ ⇓	| $R_{0.5\text{-}1.2m}$	✗	t u E (P)	⧖ c
Yam (Five leaflet yam)	Dioscorea pentaphylla *(L.)*	◎✓	❖ ⌀	⊙	③ ⇓	| $R_{0.5\text{-}1.2m}$	✗	t E (P)	⧖
Kaukau (Sweet potato)	Ipomoea batatas *(L.) Lam.*	$○_{400}$✓	❖	☼-⊙	② ≅ ⇓	$A_{0.2\text{-}0.4m}$	✗ f ⇔	t l E P M V[2]	F
Tapiok (Cassava)	Manihot esculenta *Cratz*	$○_{200}$✓	❖	⊙	⓪ (② ≅ ⇓)…	$(R)_{1\text{-}1.5m}$	f	t E (M) (l s)	(F) (e)
Taro konkong (Chinese taro)	Xanthosoma sagittifolium *(L.) Schott*	$○_{200}$✓	❖	⊙	⓪ ≅ ⇓	$(R)_{0.9\text{-}1.2m}$	f	t (l) E (P)	(F) (⊛) ⧖
Banana kuk (Parcific banana)	Musa (AAA Group) *Simmonds* /, M. paradisica *L.*	◎✓	❖ ⌀	☼ - ●	① ≅ - ≋ ⇓	$(R)_{1.5+2.6m}$	f ○ ⇳	u E	□ $ ⊛ ♠
Banana kuk	Musa (ABB Group) *Simmonds* / M. balbisiana *Colla*	◎✓	❖	-	① ≅ ⇓ v	$(R)_{1.5+2.6m}$	○ ⇳	u E V_{a+c}	□ ⊛
B. GRASSES, BAMBOOS AND REEDS									
Mambu (Small bamboo)	Bambusa forbesii *(Ridl.) Holttum*	◎/○✓	❖ ⌀	☼-◗	⓪	-	f ○	o	□ ⊛
Mambu (Common bamboo)	Bambusa vulgaris *Schrad.*	○✓	❖ ⌀	☼-◗	≅	-	f ○	(o)	□ ⊛ ♠ 'T' ⅄
Long pitpit (Coastal pitpit)	Saccharum edule *Haask*	◎✓	❖ ⌀	☼-◗	① ≅ - ≋	$A_{0.4\text{-}0.7m}$		o (E) P M V	(F)
Suga (Sugar-cane)	Saccharum officinarum *L.*	◎✓	❖ (⌀)	☼-⊙	① ≅ - ≋	$R_{0.5\text{-}0.7m}$		o E,M_e	(F) ($) □ ♠
Wail pitpit	Saccharum spontaneum *L.*	◎✓	❖ ⌀	☼-◗	⓪	$A_{0.4\text{-}0.7m}$		o (P)	F e
Siot pitpit/ Moi (Highlands pitpit)	Setaria palmifolia *(Koenig) Stapf*	◎✓	❖	☼-◗	⓪ ≅	$A_{0.4\text{-}0.7m}$		o (EP) $M_{ca+fe}V_a$	(F)
Kon (Corn/ Maize) °	Zea mays *L.*	□✓	⌘	☼	⓪ ⇓	$A_{0.4\text{-}0.7m}$		f E (PM)	(F) $ ⧖
C. LEAFY GREEN VEGETABLES									
'Aibika' (Okra) °	Abelmoschus esculentus *(L.) Moench*	□✓	⌘	☼-◗	① ≅	A (♈) ✂	⇳	s l P E M_{ca} V_{a+c}	⊛ P □ ♠
Abika (Aibika)	Abelmoschus manihot *L.*	◎✓	⌀ ❖	☼-◗	⓪ (①)	A		l M_p V_a	□ ⊛ ♠
(Native spinach)	Amaranthus spp.	◎✓	❖ ⌀	☼	(①)	(R)-	f ⇔	l f E (P) M_{ca} V_{a+c}	(F) ($)
(Amarath)	Amaranthus tricolor *L.*	○✓	⌀	☼	⓪	$A_{0.1m}$ ♈	f ⇔	s l P V_{a+c} M	(F)
Kumu mossong (Sand paper cabbage)	Ficus copiosa *Steud.*, F. spp.	◎✓	⌀ ⌘	⊙-●	⓪	✂	⇳	l u	□ T ⅄ P F ♠

[1] The most important of the yams, PNG has the best varieties in the world. (FRENCH 1986, 10)
[2] Food value varies greatly depending on variety

Common name in PNG Pidgin English (English)	Scientific name	Origin, risk of invasion	Wild form/ varieties	Demands to light	Demands to soil	Other demands	Ecological functions	Food value	Other values
Tulip	Gnetum gnemon *L.*	◎✓	⌘ ❖	☼ - ●	⓪ ⇓	R-A_{6m} ✂	✪ ⇳	I (f u) M_{ca} V_{a+c}	☐ T (F) ♠
Lettuce	Lactuca sativa *L.*	☐	-	☼	① ≅	▲ A ♈	-	I M_{ca} V_a	-
Wara kebis (Watercress)	Nasturtium officinale *R.Br.*	◎✓	⌘ ❖	☼	≈	A ✂	+ ✗ f ⇔	I M_{ca+fc}	$
Wara kalis (Water dropwort)	Oenanthe javanica *D.C.*	◎✓	⌘ ❖	☼	≈	A ✂	f ⇔	I M_{ca} V_{a+c}	$ (♠)
(Rungia)	Rungia klossii *S,Moore*	◎✓	⌘	⊙	(①≅)	A	-	I M_{ca}	-
Kumu manus (Water leaf)	Talinum triangulare *(Jacq.) Willd.*	◎ '	⌘	☼	⓪(≅)	A	⇔	I M_{ca} V_c	(F)
D. LEGUMINOUS VEGETABLES									
Pinat (Ground nuts)	Arachis hypogea *L.*	☐✓	⌘	☼	(②)⇓ ®	| $^{2\text{-}5}E_{0.1\text{-}0.6m}$	n f ⇔	u P F V_{b+c}	$ ⛇
(Pigeon pea)	Cajanus cajan *(L) Millsp.*	○ (✓)	⌘	☼	⓪ ⇓ …	| d $A_{1.5m}$ ✂	n f ⇳ ⇔ ✗	s I P M_{ca} V_a	F M(♁) ⊛
(Jack bean)	Canavalia ensiformis *D.C.*	☐	-	◗	⓪ …	| $A_{0.3+0.6m}$	(n)	s I f P M_{ca}	-
(Sword bean)	Canavalia gladiata *(Jacq) D.C.*	☐	-	☼	⓪ …	| d $A_{0.6\text{-}0\text{-}7m}$	n	E P M_{ca} V_a I	-
(Soybean)	Glycine max *(L.) Merr.*	☐	-	☼	① i	$A_{0.3+0.6}$	n ⇔ +	s P F M E (l) V	F ☐ ($)⛇⛇
Lablab bin (Hyacinth bean)	Lablab purpureus *(L.)Sweet/*	○✓	-	-	…	| $E_{0.3+0.6m}$	n	u s P E	-
Grinbin (Green beans)	Phaseolus vulgaris L.	☐	-	☼	① ⇓	Λ |	(n) +	u M V_{a+b+c}	-
Asbin /Konabin (Winged beans)	Psophocarpus tetragonolobus *(L.) D.C.*	○✓	❖	☼-◗	⓪	(Λ) (|) R-$A_{0.2+0.6m}$	n f	f I s t u P F E M_{ca+mg} V_a	⛇ ⛇
Kudzu (Japanese arrowroot)	Pueraria lobata *(Willd.) Ohwi*	○ W✓	⌘ ⌘	⊙	⓪	|-	n f ⇔	t E	F M ☐ e
Mangbin (Mung beans)	Vigna mungo *(L.) Hepper*	☐	-	☼	⓪⇓	| d $D_{0.2+0.5m}$	n	I s P E V_a M_{ca+fc}	⛇
(Green gram)	Vigna radiata *(L.) Wilczek*	☐	-	☼	⓪ ⇓	| d $A_{0.5\text{-}0.6m}$	n	f I EP M_{ca}	-
Snek bin (Snake bean/ Cowpea)	Vigna unguiculata *(L.) Verdc.)*	○✓	⌘	☼-◗	≅	| $A_{0.6m}$	n f ⇔	u s I E (P)	(F)
E. OTHER MORE RECENT VEGETABLES									
(Onions)	Allium sativum *L.*	☐✓	⌘	☼	①≅	(▲) $A_{0.1+0.2m}$	+	t o V_c	⛇
Kepsikem (Capsicum, Peppers)	Capsicum annum *L.*	☐ ✓	-	☼	(④)	▲ $A_{0.2+1m}$ ♈	+	u M_{ca+p} V_a	♠
Pamken (Pumkin)	Cucurbita maxima *Duch ex Lam.*	○/☐ ✓	❖	⊙	⓪	$A_{1\text{-}2m}$	✗ ⇔	u I s E M V_{a+c}	(⛇)(F)
Bottle gourd	Lagenaria sinceraria *(Molina) Standley*	○/☐ ✓	⌘	⊙	⓪-	$A_{1\text{-}2m}$	⇔	u I V_{a+c} I	(F)
Tometo (Tomato)	Lycopersicon esculentum *Miller*	☐✓	⌘	☼	① ≅	▲ $D_{1.5+1m}$ ♈ | ✂	+	u V_{a+c}	-
(Bitter gourd)	Momordica charantia *L.*	○ ✓ (W)	⌘ ⌘	⊙		|	⇔	u M_{ca} V_{a+c}	$ ♠
Sako (Choko)	Sechium edule *(Jacq.) Swartz*	○/☐ ✓	⌘ ⌘	⊙	① ≅ ⇓	| ✂	f ⇔	u E I M_{ca} V_a	(F) ⛇
Snek bin (Snake gourd)	Trichosanthes cucumerina *L.*	◎ ✓	⌘	⊙	(①)	| $A_{0.5m}$		u (E) V_a	$ ⊛
F. MINOR WILD VEGETABLES/ FOOD									

Common name in PNG Pidgin English (English)	Scientific name	Origin, risk of invasion	Wild form/ varieties	Demands to light	Demands to soil	Other demands	Ecological functions	Food value	Other values
Kumu (eible ferns)	Asplenium, Athyrium, Diplazium, Dryopteris.	◎✓	⌘ ⌘	⊙-●	≅	-	⇔	L	F
Kumu gras (Fern)	Athyrium asperum *(Bl.) Copel*	◎✓	⌘	◗	≅	-	⇔	I	-
Kumu gras (Fern)	Athyrium esculentum *(Retz.) Copel*	◎✓	⌘	◗	≈	-	-	I	-
(Cobbler´s pegs)	Bidens pilosa *L.*	○✓ W	⌘	☼	⓪	-	f ⇔	s I	F (♠)
(Job´s tears)	Coix lachryma-jobi *L.*	◎/○✓	⌘	◗	⓪ ≈	-	-	s P M E	⊛ ☐ ⛇
(Wandering Jew)	Commelina diffusa *Burm.f.*/ Tradescantia	○✓ W	⌘ ⌘	☼-◗	⓪ ≅	-	-	I?	
Kumu (Tree ferns)	Cyathea angiensis *(Gepp.) Dom.* +C. contaminans *(Wall. Ex Hook.) Copel*	◎✓	⌘ ⌘	⊙-●	≅-≈	-	⇳	L	⊛
(A wild creeping legume)	Desmodium microphyllum *(Thur. DC.)*	◎ '	⌘	◗	⓪	-	⇔ n	I P	-
Kankong	Ipomoea plebeia *R.Br.* I+ hederifolia *L.*	☐✓ W!	❖ ⌘	☼-⊙	⓪ ≅	-	⇔	I P M_{ca} V_{a+c}	-
Salat (Nettles)	Laportea interrupta *(L.) Gaud*	◎✓ (W)	⌘ ⌘	◗	⓪ ≅	R	(⇳)	I	♠
(Horseraddish /Drumstick tree)	Moringa oleifera *Lam.*	○	-	-	⇓	✂	⇳ M f	I P V_{a+c} s (r) M_{ca}	-
(Wild bean)	Mucuna albertisii *F. v Muell*	◎	⌘	☼-⊙	-	-	n ⇔	s P	-
(Fei banana)	Musa maclayi *F.Muell ex* / M. troglodytarum L.	◎✓	⌘ ⌘	☼ - ●	⓪ ≅ ⇓	(R) $_{1.5+2.6m}$	✪ ⇳	u E	☐ ⊛ ♠
-	Pipturus argenteus *(Forst.) We*	○	⌘	◗	≅	-	⇳	I u	(♠) c
Karakap (Blackberried nightshade)	Solanum nigrum *L.*	◎/○✓ (W)	❖ ⌘	☼-⊙	-	$A_{0.4m}$ ✂	-	I (u) (P) M_{ca} V_{a+c}	$
G. NON WOODY FRUIT CROPS									
Painapol (Pineapple)	Ananas sativus *(Lindl.) Schult.*	☐✓	⌘	⊙	① ≅ - …⇓	d $A_{0,2+0,6m}$	-	u $V_{a,b+c}$ E	$⊛
Waramelen (Water melon)	Citrullus lanatus *(Thunb.) Mansf.*	☐✓	⌘	☼	② …⇓	$D_{1\text{-}1.5m}$	⇔	u V_a M_{ca}	$
(Lady´s finger banana)	Musa (AAB Group) *Simmonds*	○	⌘	☼-⊙	① ≅ ⇓	$R_{2\text{-}3m}$	⇳	u E	-
(Pacific plantain)	Musa sapientum (AAB Group) *Simmonds*	◎✓	⌘	☼-⊙	① ≅ ⇓	R	✪ ⇳	u E	☐ $ ⊛
Suga prut (Passionfruit)	Passiflora edulis *Sims*	☐✓	❖	⊙	⓪ ⇓	| ▲ A	-	u E V_c	⊛
(Yellow granadilla)	Passiflora laurifolia *L.*	☐✓	-	⊙	-	| ▲ A	-	-	-
H. CULTIVATED FRUIT TREES AND PALMS									
Sapsap (Soursop fruit)	Annona muricata *L.*	☐✓	⌘	⊙	⓪…⇓	(▲) $A_{3\text{-}4m}$	✂ ⇳	u V_{a+c} E	-
(Sweetsop)	Annona squamosa *L.*	○	-	☼	⓪…⇓	(▲) $A_{3\text{-}4m}$	✂ ⇳	u V_{a+c} M_{ca} E	-
Faiv kona (Carambola)	Averrhoa carambola *L.*	☐✓	⌘	⊙	⓪	A_{6m}	⇳	u V_{a+c}	-
Popo (Pawpaw/ papaya)	Carica papaya *L.*	○✓	❖ ⌘	☼	⓪ ≅ ⇓ ⩤	(▲) A_{2m}	f ⇳	u V_{a+c} E	($) F ♠ ☐
Swit muli (Lime)	Citrus aurantiifolia *(Chrism.) Swing.*	○✓	⌘	-	⓪ …- ≅⇓	(▲) $A_{4\text{-}5m}$	✂ ✪ ⇳	u $V_{(a)+c}$	⊛ ($)
Pamelo (Pomelo/ shaddock)	Citrus grandis *(L.) Osbeck*	◎✓	⌘ ⌘	☼-●	⓪ …- ≅⇓	(▲) A_{8m}	✂ ✪ ⇳	u V_{a+c} M_{ca}	⊛

Common name in PNG Pidgin English (English)	Scientific name	Origin, risk of invasion	Wild form/ varieties	Demands to light	Demands to soil	Other demands	Ecological functions	Food value	Other values
Pait muli (Lemon)	Citrus limon *(L.) Burm. f.*	○✓	⌘	☼	◎ ⇓	(▲) A_{4-5m}	✂ O ⇳	u $V_{(a)+c}$ M_{ca}	⊛ ($) ♠ ☐
Mandarin (Mandarin)	Citrus reticulata *Blanco*	○✓	⌘	☼	◎ ⇓	(▲) A_{8m}	✂ O ⇳	u V_{a+c} M_{ca}	⊛ ($)
Swit muli (Orange)	Citrus sinensis *(L.) Osbeck*	○✓	⌘	☼	◎ ⇓	(▲) A_{8m}	✂ O ⇳	u V_{a+c} M_{ca}	($)
Mengo (Mango)	Mangifera indica *L.*	○✓	✣	☼-	ⓘ…	▲ A_{15m}	O ⇳	u V_{a+c} (E P)	$ ♁ ♠
Lamatang ? (Rambutan)	Nephelium lappaceum *L.*	○✓	⌘	☼-●	≅	▲ A_{10m}	O ⇳	u E M_{ca} V_c s	($)
Bata (Avocado)	Persea americana *Mill.*	○✓	⌘	☼	◎ ≅ ⇓	▲A	O ⇳	u P $V_{a, b+c}$ E F	F ($) ☐
Ton (Taun/ Oceanic lychee)	Pometia pinnata *Forst.*	◎✓	✣	●	(≈)	-	M O ⇳	u	T ☐ (♁) $
Yambo (Guava)	Psidium guajava *L.*+ P. cattleianum *Sabine*	○✓ W!		☼-◗	◎ ≅ - …	▲ A_{6m}	O[3] ⇳	V_c $M_{fc,ca,p}$	♠
I. SEMICULTIVATED OR WILD NUT/FRUIT TREES									
(Candlenut)	Aleurites moluccana *(L) Willd*	◎		◗-●	≈	▲[4]	O ⇳ f	s E F P M_{ca}	⊛[5] T♁ ☐ P (♠) ($)⚹
Kapiak (Breadfruit trees)	Artocarpus altilis *(Park.) Fosberg,* A. marianennsis ssp.	◎ ✓	✣	☼-●	≈ - …	(▲) A_{10m}	O ⇳	u E V_{a+c} M s P I	☐ (F) T ⊛ (♠)⧖
Pao (cut nut)	Barringtonia procera *(Miers) Knuth*	◎		◗-●	≈	-	O ⇳	s P N	$
Bukubuk	Burckella obovata *(Forst. Pierre)*	◎/O		●	≅	-	O ⇳	u	☐
Galip (Galip nuts)	Canarium indicum *L.*, C. mehenbethane, C. kaniense, C. salomonense	◎✓	[6]✣	☼-●	◎ ⇓	-	O ⇳	s P E F M_{ca} V_{a+c}	$ T ♁ ⧖
Limbung (Fishtail palm)	Caryota rumphiana *Becc.*.[7] (+C. mitis / urens)	◎✓	✣	●	◎ (≈)	-	f ⇳	(u) o E	☐ T c ♠
Kokonas (coconut)	Cocos nuciferra *L.*	◎ ✓	✣	☼	⇓ (≈)	A	O ⇳	s F P M_{fc+p} E[8]	[9]⊛ ♠T ♁ ☐ F P⧖
Well mengo	Corynocarpus cribbianus *(F.M.Bail) L.S. Sm.*	◎/O✓		●	⇓	-	O ⇳	u ?	-

[3] In some parts of PNG leaves are traditionally used for mulching and fertilizing yam
[4] To get very hard shelled seeds to start growing more quickly, they are burnt with dry grass and while they are still hot they are thrown into cold water, and then planted (cf. FRENCH 1986).
[5] Planted as living fencing and as boundary markers
[6] In Gurakor there are at least 7 different species and varieties according to JOHN 1997.
[7] Extensively used and propagated in Gurakor for its multi-purpose use as starchy food (marrow), for carving, arrows and bows, mats, brooms, housing material. It can also be used for the production of sugar. One palm can produce up to 1800 l juice with 15% saccharose.
[8] The meat of the nut can be eaten at all stages of development and therefore nutritional values can vary greatly.
[9] The most useful of all plants in the Pacific: in house construction for poles, rafters, and beams, for wood carving, in fencing, for animal pens, food containers, tools, spears and weapos, drums, recently for sawn timber, source of fuel: coir and dry leaves important as tinder and torch; leaves used for weaving baskets, food containers and parcels, mats, housing thatch, bandages, grass skirts, body ornamentation, , head-dresses, hats, brooms, toys, combs, for fishing, coir of husk of nuts used to make strong fibre and cordage, brushes, doormats, black dye and in a variety of other ways. Major food and fodder, coconut oil for cosmetics, copra as export crop, oil used as preservative for tapa, carvings and other objects, soft flesh of immature nuts as nutritious weaning food, juice as nutritious local beverage. Most parts are used medically (cf. CLARKE, THAMAN 1993, 231).

Common name in PNG Pidgin English (English)	Scientific name	Origin, risk of invasion	Wild form/ varieties	Demands to light	Demands to soil	Other demands	Ecological functions	Food value	Other values
Mon (New Guinea Waltnut)	Dracontomelon dao *(Blanco) Merr.&Rolfe*	◎/O		●	≅	-	O ⇳	s	T ⧖ (♠)
-	Ficus spp.	◎/O✓	✣	●	≅	-	O ⇳	u (l)	☐ (♠)
(Finschia)	Finschia chloroxantha *Diels*	◎		●	⇓	-	O	-	⊛ (T)
Well mengo (Wild mango)	Mangifera minor *Bl.*	◎✓	✣	⊙ - ●	⇓	-	O ⇳	u	(♠)
Saksak (Sago-palm)	Metroxylon sagu *Rottb.P.*	◎ ✓	⌘	●	≈	-	O ⇳ +	o E	☐ (F) ⧖
Saksak (Salomons´sago)	Metroxylon salomense *(Warburg) Becc.*	◎/O✓	⌘	●	≈-…	-	⇳ +	o E	☐ (F) ⧖
Marita	Pandanus conoideus *Lamarck*	◎✓	✣	⊙ - ●	◎ ≈	A	⇳	u[10] E F V_a,	⊛ ☐ P $
Pandanus	Pandanus spp. (cernuifolius, danckelmannianus, exiguus, krauelianus...	◎✓	✣	⊙ - ●	≅	-	⇳	s F V_{a+c}	☐
Sis (Pangi)	Pangium edule *Reinw.*	◎✓	⌘	●	≈	-	O ⇳	s P F	⚹ ☐
Laulau (Watery rose apple)	Syzgium aqueum *(Bum.f.) Alston.*	◎✓	✣	●	◎ ≅ ⇓	A_{6-8m}	O ⇳	u V_c	⊛ (T) ☐ ♠
Laulau (Jambolan/ Java plum)	Syzgium cumini *(L.) Skeels*	◎	⌘	●	◎ (≈)	-	O ⇳	u V_{a+c}	⊛(T) ♁ ☐ ♠
Okari	Terminalia kaernbachii + T. catappa *L.*	◎✓	✣	☼-●	≈- ⇓	-	O f ⇳	s P F	$ (♠)
J. NITROGEN-FIXING TREES AND SHRUBS									
(Wattle)	Acacia auriculiformis *L.*	◎	-	☼-⊙	◎ …	A_{2-4m}	n f ⇳	-	♁
-	Adenanthera pavonia *L.*	◎/O		-	-	-	n f ⇳O	l s	⊛
-	Albizia falcataria	☐ W✓	-	☼	-	(▲)$A_{1.5-3m}$	n f ⇳	-	⊛ ♁ ☐
-	Albizia moluccana + A. procera	○ (W)		☼-●	◎ (≈)	-	n f ⇳	-	-
-	Calliandra houstoniana	☐		⊙	◎	$A_{0.5-3m}$	n f ⇳	-	⊛ ♁
Cassia (Shrub)	Cassia alata *L.* , C. spp.	☐✓ W!	✣	☼-●	◎ …	-	n f ⇳	(l) E M_{ca} V_{a+c}	⊛ ♠ ⚹
Yar	Casuarina oligodon	◎✓	✣	☼	◎ …	▲A_{1-2m}	n ⇳ O	-	T ♁ (♠)
(Short-lived shrub, 1m)	Crotalaria retusa *(L.)*	○(✓) W!		☼-⊙	◎ …	A_{1-2m} ✂	n f ⇳ M	-	♁ (F)
Balbal (Coral tree)	Erythrina variegata *(L.)* Merr.	◎✓	✣	☼- ●	◎	-	n f ⇳ M O	(l) E P M_{ca} V_a	⊛ T ♁ ⚹ ☐[11]
(Nicaragua cacoa shade)	Gliricidia sepium *(Jacq.) Kunth ex Walp.*	☐	-	☼-⊙	◎	✂	n f ⇳ MO	-	⊛ (F) ♁
(Lantana)	Lantana camara *L.*	☐✓ W!	✣	⊙	◎ …	(▲)$A_{0.5-2m}$	n f	-	⊛
Landro (Leucaena)	Leucaena leucocephala	○✓W	✣	☼-⊙	◎ …	✂	n f M O ⇳	-	⊛ F ♁
-	Parasponia rugosa	◎		☼ - ●	◎	A_{1-2m}	n O	-	♁
Diwai kundu (Rosewood)	Ptecocarpus indicus	◎✓		☼ - ●	◎ ≈ - …	✂	n f M O +	-	⊛ ♠ T ♁ ☐[12]

[10] Very important cultivated tree with large, conical syncarps weighing up to 8 kg bearing numerous, bright red (rarely yellow) drupes.
[11] Used as living fence, living pig/ livestock pens, boundary marker and as a shade tree for coffee

Common name in PNG Pidgin English (English)	Scientific name	Origin, risk of invasion	Wild form/ varieties	Demands to light	Demands to soil	Other demands	Ecological functions	Food value	Other values
Marmar (Raintree/ Monkey-pod)	Samanea saman *(Jacq.) Merr.*	O✓	⊘	☼ - ●	◎ ≅	A_{6-10m}	n f M **O**	l	⊛ F ☐ T ♂
-	Schleinitzia novo-guineensis	◎	❖ ⊘	☼ - ●	◎	-	n f **O**	-	-
(Sesbania)	Sesbania grandiflora	☐	-	☼	◎ ≅/+Ⓡ	A_{1-2m}	n f M	l f P $M_{ca}V_{a+c}$	⊛
K. FLAVOURINGS, MASTICANTS OR OTHER (POTENTIAL) CASH CROPS									
Golgol	Alpinia spp.	◎✓	❖ ⊘	☼-●	◎ ≅	-	f	u s	♠ ⊛ ☐
Buai (Betel-nut palm)[13]	Areca catechu *L.*	◎✓	❖ ⊘	☼-●	-	A_{1-4m}	⇳	E P M_{ca}	♠ ⊛ ☐ $
(Annatto)	Bixa orellana *L.*	O✓	❖ ⊘	☼-⊙	◎	-	⇳	-	⊛ ☐ D[14] $ (♠)
Sili (Chili)	Capsicum frutescens *L.*	☐ (W) ✓	⊘	☼-⊙	⇓	▲ $A_{0.9m}$ ✂	+	l u M_{ca} V_c	$ ⚷
Kapok (Kapok tree)	Ceiba pentandra *(L.) Gaertn.*	O/☐✓	-	⊙-●	≅ ⇓	-	⇳ **O**	l s	⊛ T ♠ ☐[15] ⚷ $
Gam (Native Cinnamon)	Cinnamomum podagricum *Kosterm*	◎✓	❖ ⊘	⊙ - ●	≅	-	⇳	-	$ ♠ ⚷
Kopi (Robusta coffee)	Coffea canephora *Pierre ex Froehner*	O✓	⌘	⊙	-	-	⇳	-	$[16] ⚷
Oil palm	Elaeis guineensis	◎✓	-	-	-	-	-	s F	$ ♂ ☐
Cardamom	Elettaria cardamomum *Maton*	O	-	⊙ - ●	-	-	-	-	$ ⚷
Brus,(Tabacco)	Nicitina tabacum	O✓	⌘	☼	⇓	E ✂	-	-	$ ⚷
Daka (Betel pepper)	Piper betle *L.*	O✓	⊘	⊙ - ●	-	A | ✂	-	l u M_{ca} V_a	$ ♠
(Pepper vine)	Piper nigrum *L.*	☐	-	⊙	⇓	| ✂	-	u E P	$ (♠) ⚷
(Vanilla)	Vanilla tahitensis *J.W. Moore*	☐	-	⊙	⩥ [17]	|	-	-	⊛ $
(Straw mushrooms)	Volvariella volvacea	◎/O	-	⊙		-	-	-	-
Kawal (Ginger)	Zigiber officinalis *Rosc.*	◎✓	❖ ⊘	⊙	(③)	$A_{0.2-0.4m}$	-	t (M) V_a	$ ♠ ⚷

[12] Very popular for traditional drums. The bark exudes a red sap which is used as a glue for fastening the lizard skin on the to of such drums and also contains useful tannic acids
[13] Is an important social nut and masticatory chewed with lime and betel pepper, very important regional cash crop
[14] Contains dye which is used as food/fibre colour or for body ornamentation
[15] Oil of its seeds can be used to produce lamp oil or soap, cotton like fibres
[16] Major export crop in PNG, in 1985 70 % being produced by smallholders (CLARKE, THAMAN 1993, p. 233).
[17] Wood or coffee residues or banana stems and leaves as substrates (KUBE 1990, 41)

L. SOME IMPORTANT MAINLY WOODY ORNAMENTALS									
Golgol	Alpinia purpurata	◎/O✓	❖ ⊘	⊙	-	-	-	-	⊛ ☐
(Begonia)	Begonia spp.	◎/O✓	❖ ⊘	⊙/●	≅	-	-	(l o)	⊛ (♠)
-	Bougainvillea spp.	☐✓	❖	☼	-	-	-	-	⊛
-	Brassaia actinophylla/ Schefflera a.	◎/O✓	❖	⊙	-	-	⇳	-	⊛ ♠
(Coloured nettle)	Coleus spp.	O/☐✓	❖	☼	-	-	-	-	⊛
-	Cordyline australis	☐✓	❖	☼	-	-	⇳	-	⊛
Tanget	Cordyline terminalis *(L) Knuth*	◎✓	❖	☼-⊙	-	-	⇳	t E	⊛[18] e ♠ ☐
(Tulip tree)	Datura suaveolens/ arborea	☐✓ W	⌘	☼ - ●	-	-	⇳ +	-	⊛
(Poinciana)	Euphorbia pulcherrima/ Delonix regia	☐✓ (W)	❖	⊙	-	-	-	-	⊛
(Heliconia)	Heliconia indica *Lam.*	◎	❖	●	-	-	-	-	⊛ ♠ ☐
Hibiskus (Hibiscus)	Hibiscus rosa-sinensis + H. tiliaceus	◎/O✓	❖	☼-⊙	✂	-	⇳	(l) f V M	⊛[19] ♠ F☐
Redpela rop plaua (Flame of Iran)	Mucuna benettii	◎✓	⊘	⊙ - ●	-	|	n (M)	-	⊛ (s F)
Indigenous orchids	Orchidaceae	◎✓	❖	⊙- ●	-	-	-	-	⊛ ♠☐
(Frangipani)	Plumeria alba + P. rubra *L.*	O-☐✓	⌘	⊙	-		**O**⇳	-	⊛ ♠☐
Travellers tree	Ravenala madagascariensis	☐✓		☼	-	-	⇳	(s)	⊛

[18] Very important decorative ceremonial and magico-religious plant with numerous cultural uses like body ornamentation, garden marker to ward off evil spirits and black magic and traditionally important food
[19] Commonly planted as living fence and living pen.

[17] Wood or coffee residues or banana stems and leaves as substrates (KUBE 1990, 41)

L. SOME IMPORTANT MAINLY WOODY ORNAMENTALS									
Golgol	Alpinia purpurata	◎/O✓	❖ ⌀	⊙	-	-	-	-	⊛ □
(Begonia)	Begonia spp.	◎/O✓	❖ ⌀	⊙/●	≅	-	-	(l o)	⊛ (♠)
-	Bougainvillea spp.	□✓	❖	☼	-	-	-	-	⊛
-	Brassaia actinophylla/ Schefflera a.	◎/O✓	❖	⊙	-	-	⇳	-	⊛ ♠
(Coloured nettle)	Coleus spp.	O/□✓	❖	☼	-	-	-	-	⊛
-	Cordyline australis	□✓	❖	☼	-	-	⇳	-	⊛
Tanget	Cordyline terminalis *(L) Knuth*	◎✓	❖	☼-⊙	-	-	⇳	t E	⊛[18] e ♠ □
(Tulip tree)	Datura suaveolens/ arborea	□✓ W	⌘	☼ - ●	-	-	⇳ ✦	-	⊛
(Poinciana)	Euphorbia pulcherrima/ Delonix regia	□✓ (W)	❖	⊙	-	-	-	-	⊛
(Heliconia)	Heliconia indica *Lam.*	◎	❖	●	-	-	-	-	⊛ ♠ □
Hibiskus (Hibiscus)	Hibiscus rosa-sinensis + H. tiliaceus	◎/O✓	❖	☼-⊙	✂	-	⇳	(l) f V M	⊛[19] ♠ F□
Redpela rop plaua (Flame of Iran)	Mucuna benettii	◎✓	⌀	⊙ - ●	-	|	n (M)	-	⊛ (s F)
Indigenous orchids	Orchidaceae	◎✓	❖	⊙- ●	-	-	-	-	⊛ ♠□
(Frangipani)	Plumeria alba + P. rubra *L.*	O-□✓	⌘	⊙	-		O⇳	-	⊛ ♠□
Travellers tree	Ravenala madagascariensis	□✓		☼	-	-	⇳	(s)	⊛

[18] Very important decorative ceremonial and magico-religious plant with numerous cultural uses like body ornamentation, garden marker to ward off evil spirits and black magic and traditionally important food
[19] Commonly planted as living fence and living pen.

LEGEND:

- = no information available

Origin/risk of invasion:

◎ = indigenous/ early aboriginal introductions

O = traditional, naturalised post European-contact introductions

□ = recently imported

(W)= naturalised escapees from cultivation

W = invading seminatural /disturbed land

W! = serious widespread invadors also in natural habitats

✓ = present in Gurakor

Wild form/ varieties:

⌘ = with some local or regional varieties

❖ = with many (local and regional) varieties

⌀ = also wild form used

Demands to light:

☼ = sunny position

⊙ = shade prevents weed growth/ shade tolerant

◗ = shady place

● = in rain forest/ bush

Demands to soil:

() = grows best in

⓪ = tolerates poor soil

① = rich in organic matter/compost rich

② = light sandy soil

③ = deep and loose soil

④ = fertile loamy soil

≋ = swampy/ littoral conditions

≅ = moist conditions

... = dry conditions/drought resistant

⇓ = well drained

◺ = wood for epiphytes

i = seeds need to be inoculated with bacteria

Other demands:

Time of planting:

A = any season if enough rain available

R = start of rainy season

E = end of rainy season

D = dry season

Spacing in m

() = best

| = (vines) needs support

Λ = weeding

♈ = watering

▲ = best to germinate in seed bed /nursery first

✂ = pruning possible/ supports higher yields

Ecological service function:

() = of minor importance

n = N-fixation

f = fast growing/ very productive

⇔ = good ground cover

⇳ = good soil fixation/deep rooting

✦ = protective plant to control insect pests

✗ = suppresses weeds/grasses

O = provides good shade

M = provides mulch material

Food value:

() = of minor importance

l = leaves

s = seeds

t = also tubers/ roots

f = flowers

u = fruits /(young) pods

o = shoots, or inner stems,

i = inflorescence

P = high protein value

E = high energy value

V = high proportion of vitamins

M = high proportion of minerals

e = used as emergency food

⚒ = processing necessary

Other values:

() = of minor importance/ not in Gurakor

$ = regional/ export cash crop

⊛ = ornamental plant

♠ = medicine

T = timber

F= fodder

P = paints or dyes

♁ = fire wood

□ =material for handicraft or tools,
= for instruments, fibre

⧖ = storable/emergency food

Inventory of suitable traditional and introduced species for the low altitude or lower montane subsistence agroforestry in PNG (cf. GOELTEN. 1990; FRENCH 1986; CLARKE, THAMAN 1993, 198pp; CRONK, FULLER 1995, HENTY, PITCHARD 1988; KREMNITZ 1988; POWELL 1982, 212pp; SWIFT, NALU 1981; WOODLEY 1991)

3.M. MEDICINAL PLANTS AND THEIR USES IN GURAKOR

Local/ common names (scientific name)	Description (chemistry, cf. WOODLEY 1991)	Medical use
Gwella velia/ Golgol (Amomum aculeatum *Roxb.*)	Leafy shoots 2-4m high with rhizomes and edible fruits	Insect bites, swollen skin, colds or fever is treated with sap obtained by beating young leaves.
Gwella/ Golgol (Amomum sp. *Roxb.*)	Similar like the last but larger rhizomes, growing only in mature forests	Sap obtained by beating young leaves, mixed with water and salt or just eaten raw with salt to treat strong colds and cough with blood.
(Cassia alata *L.*)	Leguminous small shrub or herb, widespread ornamental (small amounts of alkaloids)	Leaves crushed and rubbed on the infected skin (grille). Also used to treat ringworm. -
(Clematis papuasica *Merr. & Perry*)	Vine	Young leaves are crushed and sniffed to clear blocked nasal passages. Rubbed on skin to treat grille
Kokonas/ Coconut (Cocos nucifera *L.*)	Palm (a number of simple ketones and an alcohol)	Stem is heated over a fire and the extract is applied to fresh knife or axe wounds.
Kekumbe (Cycas sp. *L.*?)	Tree fern with brown hairs	Stem is scraped with knife, mixed with water and drunken to treat diarrhoea, stomach ache or just rubbed on swollen/ aching skin, ulcers or burns.
Aibika (Hibiscus manihot *L.*)	Perennial herb or subshrub	Leaves are boiled rubbed on scabies or other skin diseases. Solution in cold water used to pull out a spear or splinter. Applied to sores, bruises, ulcers.
Salat (Laportea decumana *(Roxb.) Wedd.* and L. interrupta (*L.) Chew.*)	Perennial shrub or tall herb, with long irritant hairs.	Leaves with their stinging hairs are rubbed into the body to alleviate aches, pains and muscular fatigue.
Kolowagi (Merremia peltata *L. Merr.*)	Large climber or liana. to 30m high, edible tubers.	Rope as umbilical bandage. Heated young leaves are used to treat umbilical hernia. Leaves cooked and sap is used on sores or swellings.
Gnajam (Paspalum conjugatum *Berg.*)	Perennial grass and aggressive weed (methyl ether of lupeol)	Solution from squeezed leaves applied to new cuts/ sores or squeezed and mixed with lime.
Bella/ Daka (Piper betle *L.*)	Epiphytic climber with cylindrical fleshy fruits (mainly antiseptic, analgesic and anaesthetic eugenol and sedative eugenol methyl ether)	Crushed leaves used as an antiseptic on wounds, or chewed with lime and spit on wounds and abscesses.
Guava (Psidium guajava *L.*)	Shrub or small tree, 3-6m tall. Berries edible fruits	Leaves chewed with traditional salt to treat diarrhoea colds and influenza
Diwai kundu/Rosewood (Pterocarpus indicus *Willd.*)	Fast growing large leguminous tree (sapogenins)	Bark sap drunk to stop diarrhoea. Leaves used to treat stomach ache, malaria and wounds. Flowers or leaves used to relieve headache.
Bunde (Scheffleria sp. *Forst.*)	Tree with milky sap. (alkaloids)	Stem sap is collected and drunk with cold water to cure diarrhoea and pneumonia.
Brumstick (Sida acuta *Burm.*)	Erect sub-shrub, 1-1,5m tall common weed.	Young leaves rubbed on skin during bathing to treat skin pain.
Laulau (Syzygium malaccense (*L.) Merr. & Perry*	Large tree with edible pink fruits (essential oils)	Sap squeezed from the leaves to treat severe coughs, diarrhoea and stomach ache. Scraped bark, mixed with water, is applied to sores.
Kawal (Zigimber officinale *Roxb.*)	Leafy stems to 50 m high, leaves dark green, long narrow blades (many sesquiterpenes, monoterpenes, flavonoids and lignans)	Rhizome is chewed to treat stomach ache, diarrhoea malaria fever, coughs, influenza. Rubbed on head to relieve headache. Crushed rhizome mixed with lime and left on a sore.

Local/ common names (scientific name)	Description (chemistry, cf. WOODLEY 1991)	Medical use
Gam (Cinnamomum sp. *Kosterm.)* (cf. fig. I)	Large tree (alkaloids, large amounts of eugenol and varying amounts of safrole)	Bark is ground and eaten or cooked with water to treat malaria aches, colds and a variety of aches, or rubbed on aching skin/ head. Protects children from sickness.
Ngaesung (Ficus sp. ?) (cf. fig. II)	Large tree	Leaves are crumbled and sniffed to treat asthma and other disease, leaves are rubbed on skin to treat sores.
Gwimbegwa (cf. fig. III)	Climber	Young leaves are crushed and sniffed to clear blocked nasal passages.
Gwambenza (cf. fig. IV)	Perennial herb along creeks	Fleshy stalks are scraped and drunken with water or cooked and rubbed on the breast to treat colds.

Fig. I: Dry leaves and bark of Gam, Gurakor, 1997 (left side, top).

Fig. II: Ngaesung planted close to homestead in Gurakor, 1997 (left side, middle).

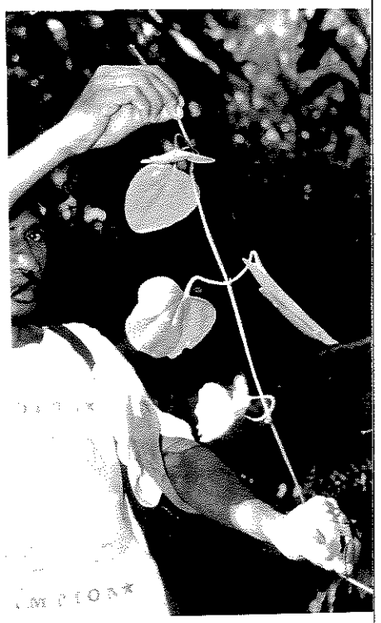
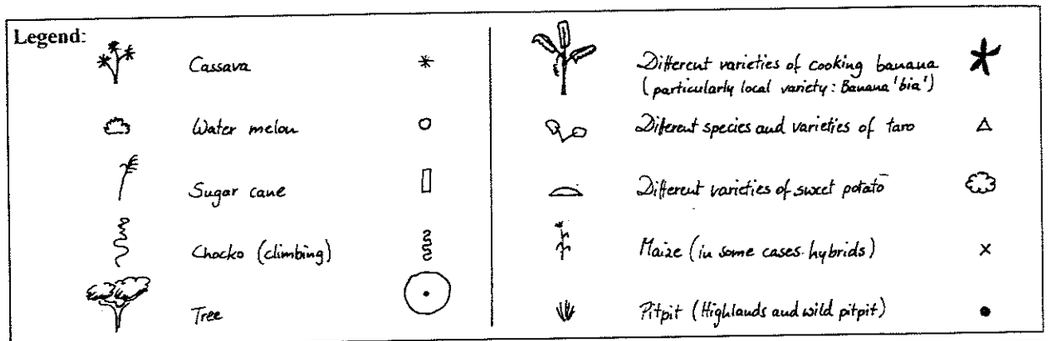


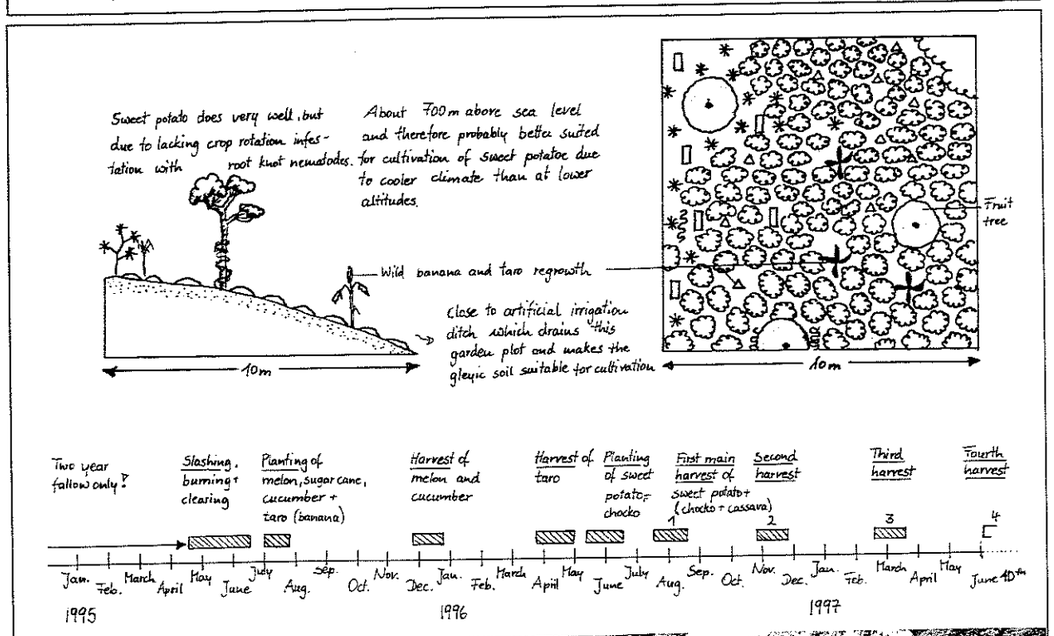
Fig. III: Gwimbegwa in Gurakor's mature forests, 1997 (top).

Fig. IV: Man in Gurakor scraping Gwambenza sticks with knife, 1997 (bottom).

Appendix 4: Examples of cropping systems in Gurakor

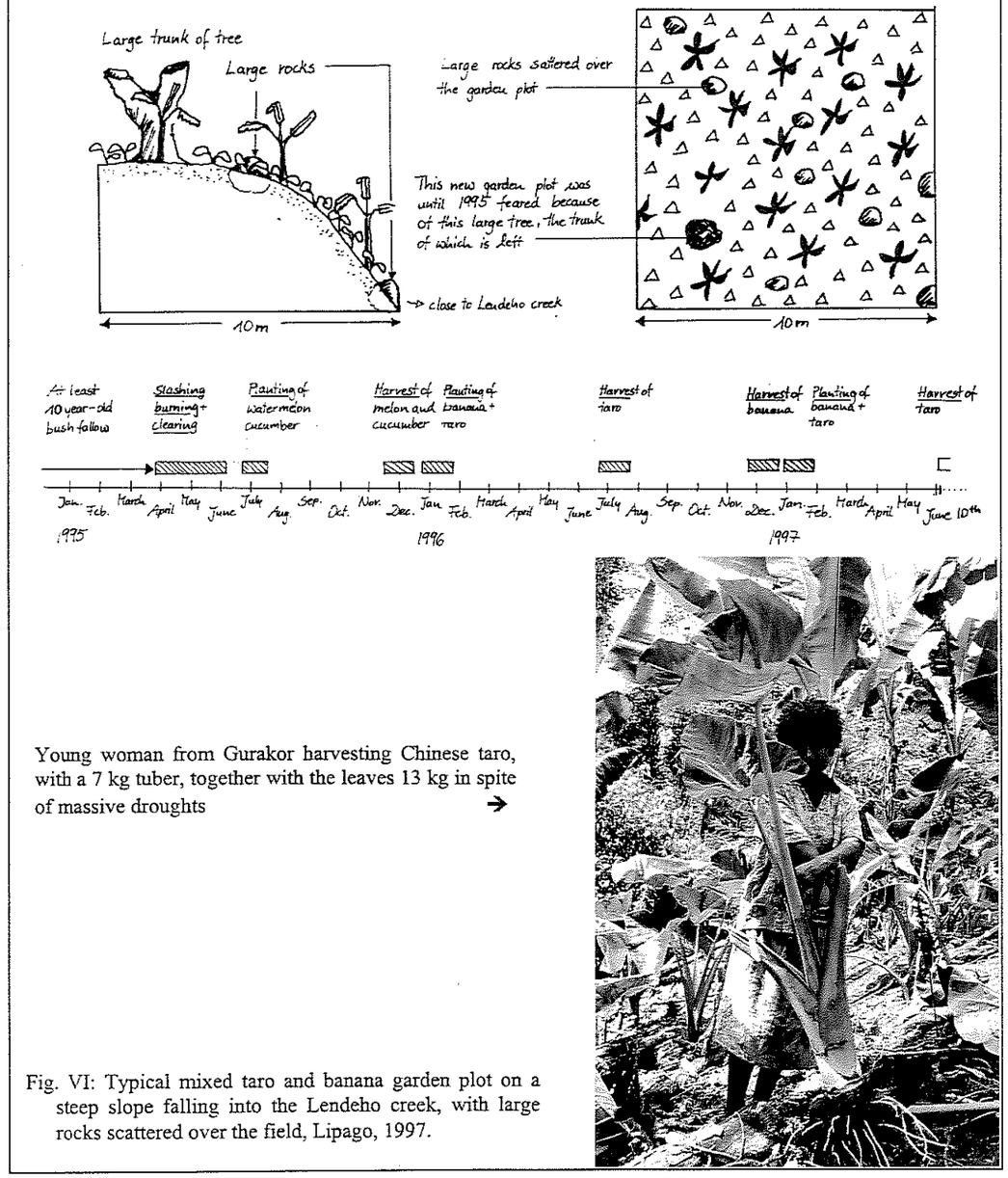
In this section four typical examples of cropping cycles show the variety of fallow periods and planting schemes in Gurakor. For each of these examples a little map and the front section is drawn and the time crop rotation since the last slashing and burning is visualized.





Two women harvesting sweet potato for the fourth time on this plot. In this area (Lipago) sweet potato was recorded to be most tasteful and productive →

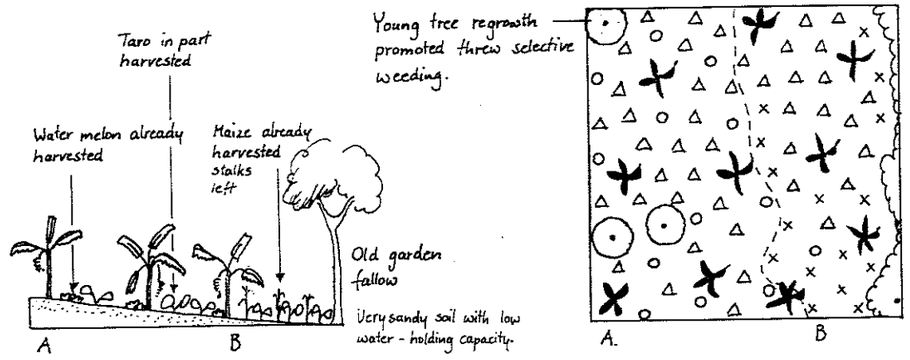
Fig. V: Garden plot over 700m above see level with sweet potato for already one year, Lipago, 1997.

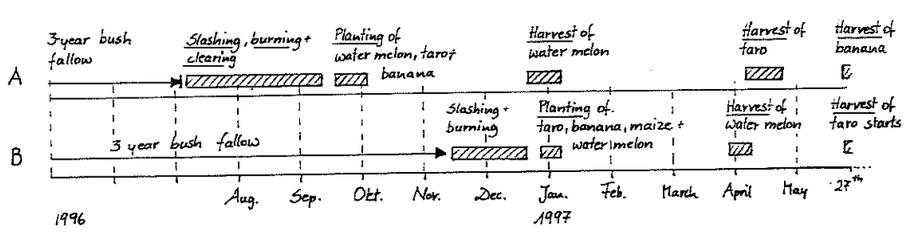


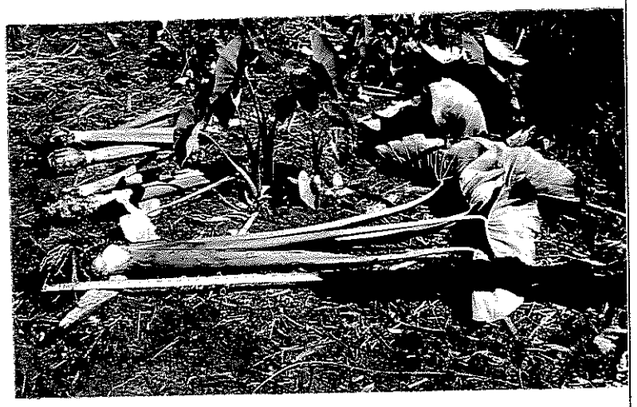
Young woman from Gurakor harvesting Chinese taro, with a 7 kg tuber, together with the leaves 13 kg in spite of massive droughts →

Fig. VI: Typical mixed taro and banana garden plot on a steep slope falling into the Lendeho creek, with large rocks scattered over the field, Lipago, 1997.

The following garden plot (Fig. VII) was for a long time feared and unused due to its close vicinity to the cemetery but is since several years taken under cultivation by a young man. The relatively low weights of taro are on the one hand common with lover yielding but tastier and more nutritive traditional varieties but are to the most extent a consequence of the droughts in 1997 which may on the very sandy soil with low water holding capacity on this garden plot particularly limiting plant growth.





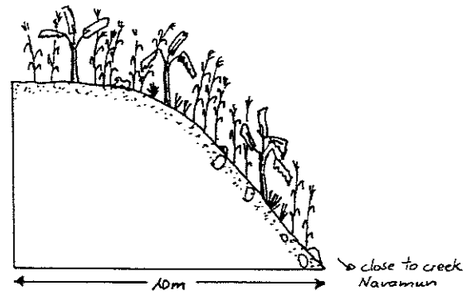


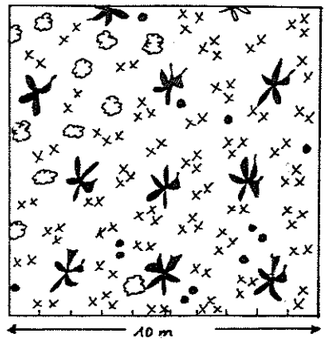
←A: Young farmer harvesting a 9,5 kg rope of a traditional cooking banana. In the background deliberately left fast growing timber trees (probably Gmelia arborea).

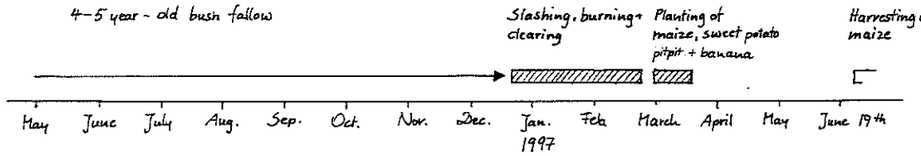
↑B: Taro plants had a weight between 4 and 6 kg, depending on species and variety. Soil prone to erosion and sun during droughts.

Fig. VII. A Mixed garden plot with banana, taro and deliberately promoted trees for building timber
B three months later enlarged, Gulgho, close to cemetery, 1997.

The last example shows a garden plot that was preferably planted with maize for marketing but still intercropped with sweet potato, pitpit and later maturing cooking banana.







Women from Gurakor harvesting 36 kg marketable maize combs within 100 m^2 together with some relatives. At least some more 6 kg smaller combs were left on the garden site or eaten in the field as there is no point to carry the heavy load back to the village. The plants are very high growing but have relatively small combs. After harvest the vegetative parts were cut off and thrown into the creek nearby instead of using residues as valuable mulch. This shows that there are considerable losses an in part ineffective use of resources. →

Fig. VIII: Maize field with interplanted banana, pitpit and sweet potato, Nendakuem, 1997.

Appendix 5: Some hints for effective use of companion plantings and wastes

5.A. SOME COMPANION CROP COMBINATIONS	
Choco	Corn, Pigeon pea, Cassava
Sweet Potato	Okra, Eggplant. Tomato, Chili, Wingbean, Lima Bean, Rice Bean, Amaranth
Cassava	Choco, Kangkong, Nightshade, Lettuce, Garlic, Vine pumpkin, Peanut,
Taro	Choco, Kangkong, and underneath any crop grown on a trellis
Tomato/Eggplant/Okra	Choco, Kangkong, Vine pumpkin,
Corn	Okra, Tomato, Choco, Bush beans, Pole beans, Cabbage, Peanut, Vine pumpkin
Vine pumpkin, Bottle gourd, Sponge gourd	on trellis: Bottle gourd, Sponge gourd, Cucumber, Bittermelon
Kangkong	Taro, Choco, Cassava, Tomatoes, Okra, Corn, Eggplant, any crop on trellis, Amaranth
Vine/Legumes	on trellis: on corn stalk, on banana stalk, leguminous trees
Yam	on fruit trees or trellis, leguminous trees
Cucumber	Corn, Pole beans, Okra, Eggplant
Tomatoes	Choco, Lettuce

(modified according to UNICEF undated, 49, table 9)

5. B. SOME TROPICAL MATERIALS FOR USE AS ORGANIC FERTILIZER OR MULCH			
Material	**Nitrogen**	**Phosphorus**	**Potash**
Corn cobs	X	X	XXX
Corn solage/stalks	X	X	X
Peanut shells	X	X	X
Egg shells	X	X	X
Feathers	XXX	X	X
Sugar by-product	X	XXX	X
Coffee grounds	X	X	X
Fish bones	XX	XX	XX
Banana stalk/skins/leaves	X	XX	XXX
Tobacco leaves/stalk	XX	X	XX
Cattle manure	X	X	X
Chicken manure	XX	X	X
Swine manure	X	X	X
Bat manure	X	XXX	X
Duck manure	X	X	X
Horse manure	X	X	X
Human manure	X	X	X

LEGEND: XXX = Good source XX = fair source X = Poor source

(modified according to UNICEF undated, 38, table 1)

Appendix 6: PNG Biodiversity and Resource Management Programme

A truly participatory way in resource management is promoted by the PNG Biodiversity and Resource Management Programme for the community entry to Integrated Conservation and Development Projects (=ICAD). Western models of National Parks for nature conservation do not work on customary owned land like in PNG because the landowners have nothing to gain by such an approach. Because of the necessity to integrate Wildlife Management Areas (=WMA) into an ICAD approach and because of customary ownership in PNG, ICAD projects with protected areas must be largely community-owned and–driven. The ICAD approach tries to avoid the problems when money drives the process rather than a belief in conservation needs (cf. above). Economic and other development incentives (which could be AF improvements) shall be integrated, too, because it would be unfair to expect villagers to carry all cost of national conservation initiatives. However, main focus is set on a 'community approach'- analysing the clan's history, its needs, and visions for the future without talking much about conservation. This approach tries to truly motivate people to carry out and reflect activities which address their basic needs and therefore assesses first where the communities strongest motivation to action really lies. A good relationship between outside institutions and communities has to be established building trust by the villagers (cf. ORSAK 1997, 8p). Although this approach seems to be very promising it is only applied selectively in sites of special interest for conservation.