TCP/TON/3104 (D)

MISSION REPORT

TECHNICAL ASSISTANCE IN THE DEVELOPMENT LAND USE POLICY IN THE KINGDOM OF TONGA (TCP/TON/3104 D)

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FAO/SAP
September 2008

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EXECUTIVE SUMMARY

1. This document consists of an Executive Summary and four main sections: an introductory part explaining the background to the development of a national land use policy in Tonga (chapters 1 and 2), a descriptive account of the present situation in the country (chapter 3), an analytical examination of the problems and issues considered as being of direct relevance to the policy (chapter 4), and recommendations for the development of the policy (chapter 5).

2. Basic reliable information is a prerequisite for land use planning. This information is often not available in Tonga. Hence, relevant ministries and departments should urgently identify the data requirements for reporting on developments in relation to land, land use, land tenure, crop suitability and land management, and should consequently organise their own operations in accordance with acceptable norms. Agencies should, in addition, be made aware that data sharing does not affect their institutional power but are a tool for an open dialogue and integrated approach to a more efficient land use in the country.

3. Land is no more a free gift, but a commodity that becomes scarce. As it is now also a direct income generator, the competition for it will grow and conflicts might arise between various users, either individuals or whole sectors of the economy. To avoid land conflicts there is an urgent need for planning and for the development of an integrated land use policy which should deal with all the sectors of the society and, therefore, should have overriding power over sector policies. All policies should be put in line with this overall land policy.

4. The Kingdom of Tonga is faced with an important migration trend resulting in a rapid development of urban areas. At the same time the country's foreign trade report shows a dramatic imbalance, with imported consumer goods exceeding exports by a factor of almost 20 in 2007. This urges for a modernisation of Tonga's agriculture, and for a more efficient crop production.

5. To increase agricultural outputs the former traditional slash and burn farming system has to be abandoned and modern farming techniques introduced. Increasing the efficiency of farming systems should have priority over the extension of crop land. Nevertheless, it is recommended that all land under fallow which is currently not used should, by law, be opened for production, either as farmland or for reforestation.

6. Modern farming techniques as currently applied in the country rely on a mechanisation of field operations, the enlargement of field sizes, seed and crop selection, and the use of agrochemicals. These practices lead in the long run, however, to the degradation of land, in particular to the deterioration of soil structure, compaction of subsoils, and ultimately to soil erosion. It is strongly recommended to explore the possibilities of conservation farming for introduction in Tonga. As these are based on minimal tillage, the introduction of cover crops and accumulation of organic material in the soil, and a reduction in the use of fertilizers and pesticides, these principles meet exactly Tonga's major future land use challenges.

7. The Kingdom of Tonga has a high potential for the production of both root crops for the local markets and tropical fruit and vegetable crops for export. Maize can be grown as a feeder crop for poultry. The selection of crops and cropland should be based on land

suitability assessments. Sustainable production methods should rely on scientifically sound fertilizer recommendations supported by appropriate soil analyses to avoid pollution. There is a need for the establishment of a technical and scientific research unit, and for a well qualified extension staff for assisting and training farmers in more environment-friendly farming techniques and fertilizer uses.

8. There is a lack of information on the nature and quality soils and on crop requirements, and this hampers both efficient farming techniques and environmental problems of soil and water pollution. To overcome these problems there is a need for proper analytical data and laboratory facilities which do not exist in Tonga. It is therefore recommended that the Government should seek an agreement with an international funding agency to install a laboratory unit, under the supervision of an international research institute, for carrying out a number of key analyses like pH, cation exchange capacity, organic material and NPK contents (chemical properties), as well as soil texture and soil density (physical properties). This laboratory should by preference be linked to the already existing research institute in Vaini.

9. The analytical information obtained from the soils and water laboratory refered to above might also help in establishing norms and standards for pollution of soil and water. The implementation of these environmental conditions will require the adaptation of the existing, or enactment of a new legislation, with enforcement procedures and penalties included. Likewise should the role of Environmental Impact Assessments (enacted but not implemented in Tonga) be recognised. In this environmental concern, forests and forest vegetation should be given a major role in protecting coastlines, preserving terrestrial biodiversity and ground water quality, and breaking the damaging effects of cyclones and erosion.

10. The Land Act (1988) is the basic law, overriding all other legislations, that defines the forms of access to land, land registration and land use. The Act has, however, no proper by-laws and regulations to implement and enforce its legislation, and this creates confusion and ambiguities in a the case of land use conflicts. In first instance, its provisions should be updated, i.e. in revising and adapting the lease system to modern forms of land use. In the longer term, the review of the Land Act may indicate that more fundamental adjustments be required to land leasing in Tonga, and to its related tenurial framework. In this context it is recommended that the land law be reviewed and considered for updating as an interim measure, with appropriate adjustments, to bring it in line with current practices and requirements.

11. As a direct follow-up of the foregoing, it is recommended that the implementation requirements for the land law be reviewed and work processes redesigned to ensure that the relevant departments have the capacities and direction to implement their responsibilities in an appropriate manner. Implementation of the law means in the first place that the legislation is effectively enforced and that tresspassers be penalised.

12. In the same line it is recommended that the review of the land law should consider the longer term issues of land policy and its administration and consider the possibility of calling for a more substantial review to bring land policy into line with current circumstances in Tonga.

13. To achieve these goals it is recommended that enabling conditions be created for (1) fastening the administrative procedures for the official lease contracts; (2) installing an

independent commission to handle conflicts between lessees and lease holders on the quality of the land, and (3) making provision for soil sampling and proper interpretation of data in case of critical issues which can not be observed *de visu*, as for example nutrient mining and subsoil compaction for example.

14. The Kingdom of Tonga has no established system of spatial planning. With no forward planning and no plans, there are no guidelines to assist decision making on either strategic or local development issues. There is also no structured identification of land use issues that may arise. It is recommended that more awareness be created at institutional level, explaining the need for planning and the methods to do so.

15. Another important issue in terms of planning is that the Kingdom of Tonga has no tradition and no experience in *integrated* planning. Many line ministries have already developed their own acts and regulations, but only on a strict sector basis. These regulations overlap sometimes, and not seldom lead to confusion or conflicts with other sectors, viz. with other potential land users. This confusion is often a reason for *status-quo* and stagnation. In this context, it is recommended that planning, land use and conflict resolution are treated between sectors. This includes in particular agriculture, forestry, urban expansion and environment, which are probably the most commonly affected sectors, as well as other individual rural land users.

16. Public awareness is an integral part of developing acceptable policies, and this should be recognised in the strategies relating to developing land use and land tenure policies. Awareness creation on environmental issues is well organised at school level (posters, lessons, competitions, a national environment day, etc.). It is much less successful at institutional and policy making levels, as can be observed from the numerous infringements with little or no follow up in events related to beach mining, mangrove and forest cutting, forest encroachment, etc. A public awareness campaign should therefore also be started in introducing relevant concepts of nature protection at institutional level of the need for planning, and in particular of integrated planning.

1. PROJECT BACKGROUND

The Kingdom of Tonga comprises a population of 101,000 persons living on 36 islands. In total there are 170 islands of volcanic and coral origin in four main groups: Tongatapu and ‘Eua, Vava’u, Ha’apai and the remote Niuas. Land resources are very limited, and only 24% of the country’s 747 km² is arable. Although natural population growth is above 3% per year the high net migration rate of approximately 2% reduces the annual population increase to barely 0.3%.

Like other Pacific island countries, the Kingdom of Tonga is experiencing a number of rapid socio-economic and environmental challenges. The growth in urbanization, being the result of rural migration from both the outer islands and Tongatapu itself, has put high pressure on the land, in particular around the capital Nuku’alofa where almost 40% of the country’s total population is concentrated. This means that many former food producing farmers are now rapidly becoming net consumers, and this has a direct effect on the country’s trade balance. At present, the total value of imports overpasses almost 20 times the import; most of these imports concern daily food products. This situation can not be maintained in the long term and, therefore, requires that local food production is urgently and substantially increased.

Tonga is, however, very vulnerable from the environmental point of view. Because of their low topographic position many of Tonga’s islands are prone to natural hazards like sea-level rise, volcanic activity, earthquake and tsunami hazards. Besides, recent and future social and economic developments, including a more intensive agricultural use of land, put the country at risk for various aspects of land degradation.

Urbanization and deforestation affect many coastal and inland zones. The clearing of mangrove forests and the exploitation of beach sand for construction weakens the stabilization of the coastline and makes the island more vulnerable for coastal erosion and the intrusion of sea-water. Deforestation of inland forests for fuel wood collection and residential or agricultural development decreases biodiversity and exposes the land to erosion. Expansion of commercial farming since the mid 1980s has increased the use of agrochemicals, fertilisers and pesticides in particular. This is accompanied by a demand for oil-based energy which has risen considerably. All of this has resulted in a rise of pollution and waste products.

Being aware of the possible impacts of future environmental hazards, the Government of Tonga has recently established the Cabinet Committee on Climate Change (CCCC) to provide policy direction on appropriate adaptation and mitigation measures to government. To provide a basis for such a policy the country needs however a reliable natural resources data base and proper strategies.

The existing land legislation is outdated and is not adapted to promoting modern and efficient land use. It particularly suffers from the lack of appropriate implementing regulations and capacities for enforcement. Land tenure is closely tied to the traditional structure of society in Tonga which makes it difficult to bring land use and management in line with a market-oriented economy. The land allotment system does not encourage private development on any significant scale, inhibiting land acquisition for commercial and industrial development. In order to address these issues effectively a more wide ranging review of land policy options for the future would be necessary. This is outside the scope of the current report, which is restricted in its concerns to issues related to the efficient use of land and to leasing aspects related to it.

The Land Act (Cap 132, 1988 Ed), henceforth Land Act (1988), and its subsequent amendments, nevertheless, does present a viable foundation for a more efficient legal framework governing land issues in the short to medium term, provided some additional regulations are introduced and implemented. The Government has committed to review the leasing of land and introduce the legislative changes needed to provide greater certainty for investors and land holders, but little real progress has been made to date. In the meantime, a number of undesirable land use practices have been taking place which might have a detrimental effect on land properties and land quality in the long run.

2. OBJECTIVES AND TERMS OF REFERENCE

The strategic objective of this study is to contribute to the enhancement of socio-economic development in the Kingdom of Tonga by facilitating an appropriate policy statement for modern and efficient land management in the country. This objective involves the adaptation of the still traditional legislation on land use practices, in particular with respect to lease and land use issues, and the promotion of more efficient sustainable land management practices in accordance with the production potential (land capility and land suitability evaluations). In addition, recommendations should keep in mind the vulnerability of the country and avoid or minimize various forms of land degradation.

The immediate objective of such a land use policy is to provide a reliable basis for (a) the increase of crop production so as to meet the country's food demands and reduce the import of goods that can be grown locally, (b) the protection of the limited land area against degradation and natural or man-made environmental hazards, and (c) the settlement of land conflicts between individuals and various sectors of the economy.

The International Consultant was in Tonga from July 12 till July 30. Because his assignment did not include any travel to the outer islands the recommendations formulated in this report concern only the main island of Tongatapu, and not Tonga as a whole. For these recommendations to be used as a basis for a national policy, the present statements will have to be checked against the situation in and complemented with data from the outer islands.

The Terms of Reference for the International Consultant are listed in more detail in Annex 3 to this report.

At the end of their mission the International and National Consultants would like to thank the staff of the Ministry of Lands, in particular the GIS section for the hospitality received, and all unnamed Tongans who spent their valuable time in interviews and research for documents which were often so difficult to find.

3. PRESENT SITUATION

The Kingdom of Tonga is an archipelago of 172 islands of 747 km², 36 of which are inhabited. It is located in the Central South Pacific between 15° and 23°30' South and 173° and 177° West. The Kingdom consists of four clusters of islands: Tongatapu and 'Eua in the south, Ha'apai in the middle, Vava'u in the north and Niuafo'ou and Niua Toputapu in the far north (Figure 1). The capital Nuku'alofa is situated on Tongatapu, the largest island.

All major islands of the Kingdom have been mapped at scale 1: 25,000 covering a series of 5 topographic sheets. These maps are available in the country.

3.1. Geomorphology and Geology

Tonga's archipelago lies along the boundary of the Pacific and Indian-Australian tectonic plates. It is composed of volcanic and more or less uplifted coral islands and reefs, with an altitude between a few meters and 200-250m a.s.l.

The islands of the archipelago are all of variable height, size and form. This is because of the different ways in which they were formed and subsequently shaped over time. Tofua, Kao and Late on the western fringe of the Kingdom are steep volcanic islands, Tongatapu, Lifuka and Ma'afeva are examples of the more common types of low, more or less flat coral islands covered by a mantle of volcanic ash (tephra) ejected from volcanoes along the western margin of the Kingdom.

Most of Tonga's main islands show subdued relief, as is the case for Tongatapu. It is only on the steeper sides of some of the higher islands that the effect of topography - and of soil erosion - becomes apparent. 'Eua and Vava'u are examples of raised coral islands with a rather thick volcanic ash cover. The south of the Vava'u Group is generally composed of high volcanic and elevated limestone islands with reef communities or fringing reefs. Ha'apai is mainly composed of high volcanic and low limestone islands. The Niuas are high volcanic islands surrounded by high fringing and barrier reefs.

Tongatapu is a low, raised coral limestone island, about 35km from east to west and 15km from north to south, formed on the crest of a large submarine fold west of a deep trench (known as the Tonga trench) on the floor of the Pacific Ocean. The land is flattish and there are no permanent streams. Geological pressure on the fold has tilted the island so that the south-eastern end is now 80m above sea-level (Figure 2).

Since the emergence of the coral the surface has been covered by a 3 to 5m thick mantle of andesitic volcanic ash. The actual source of the materials is not certain: some may have originated from volcanoes such as Tofua and Kao, but most of the ash and lapilli have probably been exploded from underwater volcanoes formed during submarine eruptions.

'Eua - Lying 20kms south-east of Tongatapu, 'Eua presents a complete contrast in terms of geomorphology, characterised by rolling hills, streams and high cliffs. Most of its surface is covered by a mantle of volcanic ash up to 3 meters thick.

'Eua consists of three well-defined coral limestone terraces leading up to an older and higher landmass made up of volcanic rocks overlying very hard limestone. Beneath the limestone there are some very old volcanic rocks which form the core of the island. Each coral terrace has been deposited as a reef near sea level and has been later raised, together with the older parts of 'Eua, to form the three benches observed today. Erosion is locally important.

Ha'apai - About 160km north of Tongatapu lies the thin curving archipelago of the Ha'apai group. Its main islands are low-lying coral islands with a flat to gentle topography covered with a three meters thick mantle of volcanic ash. There are significant areas of coral sands near the coastline of most islands. Besides, there exist also some raised volcanic isles showing a characteristic range of landforms and slopes, e.g. Nomuka and Mango. Some islands are made up of rocks other than coral limestone (volcanic tuffs, marl, organic sediments).

Vava'u - This group lies 110km north of Ha'apai. The main island of Vava'u is being surrounded by a number of smaller islands which are separated from the mainland by numerous narrow channels. Besides a number of low coral isles the group contains also larger raised coral islands with a characteristic three-tiered terraced silhouette. The largest island, Vava'u, has an elevation of 213m a.s.l. at its south-western end. All islands in this group are covered by a mantle of clayey andesitic volcanic ash of several meters thick.

Western Volcanic Islands - On the western fringe of the Ha'apai and Vava'u groups lies a chain of active and recently active volcanoes such as Tofua, Kao, Late and Fonualei. These islands are made up of young volcanic materials and have generally a central core of steeper country (the volcanic cone) with a fringe of flatter land. There is little in the way of coral reef material or beach deposits around these islands.

3.2. Climate

The overall climatic picture of Tonga is determined by the South Pacific Trade Winds (SPTW) and semi-permanent South Pacific Convergence Zone (SPCZ). It is qualified as tropical wet with a dry season, influenced by tropical cyclones (between November and April). Temperatures are high throughout the year, with only a small difference between summer and winter. The rainfall is quite high with a relatively drier period, though often with a minimum of 80mm per month, in the winter.

Tonga's UNFCCC report (Tupou and Tu'i'afitu, 2005) makes reference to a general decrease in the inter-annual rainfall in central and southern parts of Tonga since the 1970s. A study comparing the precipitation figures over the last 13 years with those over the period 1971-2000 could not confirm this hypothesis.

Rainfall - The annual rainfall varies between 1700mm in the South of the archipelago (Tongatapu) and 2500mm in the North (the Niuas). It is characterised by a pronounced wet season (also qualified as the cyclone season) between November and April, and a drier period between May and October (Table 1). The wettest months are January, February and March, and the rainfall over this period attends between 250 and more than 300mm per month. Average air humidity in these months varies around 75%.

The so-called dry season is not completely without rain as it receives still some 30% of the annual precipitation. The driest months in the year generally concentrate between June and September, though months with less than 50mm rainfall (considered as being dry in agronomy) may well occur in other parts of the year. Average air humidity during this period drops to about 65% at midday.

The variations in spatial and temporal rainfall distribution in Tonga are largely attributed to cyclone activity, which can result in unusually wet periods, and an El Nino Southern

Oscillation (ENSO) which can cause prolonged drought in central and southern Tonga. The overall annual rainfall decreases from north to south. The northern islands receive more rain (e.g. 2400- 2500mm a year) than those in the south where precipitation is 1700-1750mm (Table 1).

Monthly Rainfall (mm) and Number of Rainy Days (figure between brackets)												
Ja	**Fe**	**Ma**	**Ap**	**Ma**	**Jn**	**Jl**	**Au**	**Se**	**Oc**	**No**	**De**	**Ann**
Niuafo'ou (Queen Lavinia Airport)												
306 (21)	249 (18)	303 (22)	251 (17)	166 (16)	110 (13)	136 (14)	117 (14)	146 (12	174 (15	228 (18	270 (21)	2456 (201)
Niuatoputapu (Mata'Aho Airport)												
276 (19)	255 (19)	298 (20)	256 (18)	167 (15)	135 (30)	109 (14)	97 (13)	136 (12	183 (13	186 (14	268 (20)	2366 (207)
Vava'U (Lupepau'U Airport)												
254 (19)	268 (20)	283 (21)	209 (18)	171 (15)	115 (15)	107 (16)	100 (14)	133 (13	138 (14	135 (14	234 (19)	2147 (198)
Ha'Apai (Salote Pilolevu Airport)												
164 (13)	194 (15)	228 (17)	190 (14)	107 (12)	80 (11)	90 (12)	101 (11)	111 (10	91 (11	114 (9)	149 (13)	1619 (148)
Tongatapu (Nuku'alofa City)												
174 (17)	210 (19)	206 (19)	165 (17)	111 (15)	95 (14)	95 (15)	117 (13)	122 (13	128 (11	123 (12	175 (15)	1721 (180)
Tongatapu (Fua'Amoto Airport)												
201 (17)	221 (17)	186 (18)	159 (16)	135 (16)	101 (15)	110 (14)	124 (13)	118 (12	103 (11	103 (11	160 (17)	1721 (177)

Table 1: Monthly and annual rainfall in mm for the past 30 years (1971-2000, except Fua'Amoto Airport 1980-2002) and number of rainy days for 14 years (1990-2003) over 6 stations from North (above) to South (lower station).

A detailed analysis of the monthly rainfall over the past 13 years (1994-2006) indicates that precipitation in the Kingdom is extremely variable. Average figures have therefore little meaning if not also the range of extreme values is taken into consideration. This variability appears to be more important in the southern island groups.

Table 2 depicts the monthly rainfall at Fua'amotu (Nuku'alofa Airport) over the past 13 years (1994-2006). First, the mean annual rainfall of 1702mm (Table 1) stands for values ranging from 2592mm in 1999 to 1147mm in 1995 (Table 2). Second, if we accept that a month with 50mm rainfall is considered agronomically dry (with obvious moisture stress for most crops) and a month with 80mm rainfall marginally dry, especially in soils with low moisture holding capacity, then Table 2 illustrates that crops do not only suffer in the dry winter period (June-September) but also in other parts of the year. The exemplary year in this respect is 1998 where January- February first and later April till August showed a monthly rainfall below 80mm, though the precipitation over that year as a whole was hardly 150mm below the mean value of 1702mm over the full 1994-2006 period.

The problem of crop moisture stress is the most important in soils with low moisture retention capacity, particularly when the preceding period had received less precipitation. Halavatu *et* *al*. (1993) note that in Lapaha soils, crop moisture stress may start already after three weeks of drought.

Yr	Monthly Rainfall (mm)												
	Ja	**Fe**	**Ma**	**Ap**	**Ma**	**Jn**	**Jl**	**Au**	**Se**	**Oc**	**No**	**De**	**An**
'94	248	185	44	283	99	168	173	57	141	31	180	174	1783
'95	133	137	190	86	38	164	129	21	56	31	133	29	1147
'96	533	42	216	112	169	215	39	95	77	108	54	212	1872
'97	263	356	164	163	720	17	72	157	90	116	21	112	2251
'98	13	45	329	36	53	76	62	28	96	54	367	391	1550
'99	201	487	103	331	30	146	159	245	153	301	219	217	2592
'00	434	370	413	304	132	68	227	88	78	171	65	229	2579
'01	466	150	222	159	41	155	77	149	92	33	167	157	2079
'02	132	489	285	327	84	47	235	121	199	27	102	68	2036
'03	413	30	321	78	38	16	116	221	76	62	42	135	1548
'04	84	98	253	36	127	211	164	355	262	33	38	108	1769
'05	259	15	144	313	158	172	165	133	125	317	179	49	1660
'06	194	153	137	357	34	359	70	90	101	99	43	293	1730

Table 2: Monthly rainfall at Fua'amotu Airport (Nuku'alofa) between 1994 and 2006 (deeply shadowed areas indicate months with rainfall below 50mm; moderately shadowed zones indicate months with 50-80mm rainfall).

Tropical cyclones form an integral part of the wet season. February is the month with the highest cyclone frequency. On average Tonga is affected by at least one tropical storm per year. Between 1960 and 2004 a total of 32 tropical cyclones have been registered, some of which very damaging. El Nino events seem to increase their frequency. During the cyclone season 2002-2003 which was also an El Nino year, 3 cyclones out of 5 affecting the Kingdom caused severe damage to Southern Tonga.

A direct impact of the irregular rainfall distribution, in particular during periods of continued high rainfall during the wet season (November-April), is the occurrence of **flooding** in flat areas and of soil erosion on sloping land. Flooding in Tonga is not common except in Tongatapu and in some islands of the Ha'apai group. When it occurs it is mainly located in low-lying coastal areas and is caused by a combination of prolonged heavy rain, storm tides and heavy sea swell. This flooding is often associated with the passage of a tropical cyclone or a tropical low.

Because of their intensity many rainstorms in Tonga have a high erosive impact. Sloping areas with little or no protective forest cover are most vulnerable. It is expected that **erosion** is potentially most important in 'Eua, in some sloping islands of the Ha'apai and Vava'u groups, and on the western recent volcanic isles.

Temperature - Mean annual temperatures range from 23°C to 27-28°C, with mean air humidity around 75 %. Temperature variations display higher daily and seasonal variations with increasing latitude. Mean annual temperatures vary from 27°C at Niuafo'ou and

Niuatoputau to 23-24°C in Tongatapu (Nuku'alofa), with a diurnal and seasonal range of 6°C and 2°C in the Niua's, and 6°C and 5°C in Tongatapu respectively.

Mean Monthly Minimum and Maximum Temperature (°C)												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Ann**
Niuatoputapu (Mata'Aho Airport)												
30.8 24.5	31.1 24.6	31.1 24.5	30.7 24.2	29.7 23.7	29.4 23.4	28.9 22.7	28.9 22.6	29.5 23.6	29.7 23.5	30.3 24.0	30.8 24.3	30.1 23.8
Niuafo'ou (Queen Lavinia Airport)												
30.4 23.8	30.7 24.0	30.8 24.0	30.4 23.9	29.7 23.5	29.3 23.2	28.8 22.5	28.7 22.3	29.1 22.7	29.3 23.1	29.8 23.4	30.3 22.8	29.8 23.3
Vava'U (Lupepau'U Airport)												
30.3 23.4	30.5 23.5	30.5 23.5	29.5 22.9	28.1 21.6	27.5 21.0	26.6 20.0	26.7 20.1	27.1 20.7	28.0 21.5	29.1 22.4	29.7 23.1	28.6 22.0
Ha'apai (Salote Pilolevu Airport)												
29.5 23.8	30.0 24.1	29.8 24.1	28.9 23.2	27.4 22.0	26.4 21.2	25.8 20.0	25.6 19.9	25.9 20.3	26.9 21.3	28.0 22.5	28.8 23.3	27.8 22.1
Tongatapu (Nuku'alofa City)												
29.4 23.4	29.9 23.7	29.6 23.6	28.5 22.1	26.8 20.3	25.8 19.5	24.9 18.1	24.8 18.2	25.3 18.6	26.4 19.7	27.6 21.1	28.7 22.5	27.3 20.9
Tongatapu (Fua'Amoto Airport)												
29.4 22.4	29.9 22.9	29.4 22.9	28.3 22.0	26.6 20.1	25.4 19.0	24.5 17.7	24.4 17.7	25.0 18.2	26.0 18.9	27.6 20.5	28.5 21.9	27.1 20.4

Table 3: Mean maximum and minimum temperatures over 30 years (1971-2000, except Fua'Amoto Airport, 1980-2002) in a sequence of climatic stations from North to South in Tonga.

Daily maximum temperatures are highest in February and lowest in July - August, though occasional extreme low temperatures might also occur in September. Highest and lowest registered temperatures in absolute terms were 35.0°C in Vava'u (Feb. 1979) and 33.1°C in Nuku'alofa (Feb. 2002), and 8.7°C at Fua'amotu Airport (September 1994). Temperatures of 15°C or lower are occasionally measured, mainly in southern Tonga, during the dry season.

3.3. Soils

The soils of Tonga have been relatively well studied but, unfortunately, much of the original soil reports and maps are apparently no more available, or not been made available in the country. The first reconnaissance soil survey on Tongatapu was carried out by Gibbs in 1968. In 1969 Orbell started a reconnaissance survey of Vava'u, Okoa, Pangaimoto and Utangake islands in the Vava'u group. A detailed soil survey of the whole Kingdom was made in 1975 as part of the New Zealand Bilateral Assistance Program at a scale of 1: 25,000 (Orbell, 1993). It is believed that most of these documents can still be collected from the Landcare Institute in New Zealand.

The majority of the soils of Tonga are derived from coral limestone and two layers of volcanic ash. By far the greatest proportion of soils are, however, derived from fine-grained andesitic volcanic ash. These soils have excellent physical properties, are friable, well-structured, and well-drained with moderate plant-available soil moisture and good natural fertility. This makes that they are suitable for a wide range of uses and that, with an appropriate fertilizer supply, they can be considered suitable for the long-term production of many crops.

Parent material is the most important soil forming factor. To fully understand the effect of parent material on soil formation, it is important to know how this parent material developed. On the western margin of the country there is a north-easterly line of volcanic islands, including Tofua, Kao, Late and Fonualei. The volcanoes forming these islands are the source of a blanket of ash which covers most of the raised coral and volcanic islands of the main group of Tongan islands. These volcanoes are most probably not the only sources of volcanic ash, as many old volcanoes have probably sunk beneath the sea.

Volcanoes from this western line usually produce large amounts of wind-born fine volcanic ash. Most of this ash has been blown away from the rest of the islands by prevailing south-east trade winds. Some ash accumulated on land, or was deposited there by winds from a westerly direction, or as a result of volcanic eruptions actually directing the ash towards the east.

On close examination the ash layer is found to vary in two ways. First, the size of the particles becomes smaller as one travels eastwards from the volcanoes. Second, it appears that there have been two main periods during which the ash accumulated, while it also was not all erupted from one single volcano. Rather it came from a number of different volcanoes all or some of which may have been active at the same time. Also, the two main periods of accumulation were not necessarily everywhere exactly the same, though it is probable that they are roughly of the same age. No accurate determination of the ages of the ashes has yet been carried out, but it is believed that the age of the older ash is about 20,000 years and the younger ash about 5000 to 10,000 years.

Soils formed in volcanic ash in Tonga are generally rich in calcium (Ca) and magnesium (Mg) and low in potassium (K) and phosphorus (P). Some topsoils show an obvious enrichment in K and P, and this may be attributed to natural nutrient pumping from deeper layers and leaf fall during periods of bush fallow. In this respect the chemical status of the surface layer may reflect differences in past cropping and management.

Soils of Tongatapu - Tongatapu is a raised coral platform which has been blanketed by the two distinct layers of volcanic ash previously described. These two ash layers have weathered to form fertile soils over much of the island, but smaller areas of soils have also developed from coastal deposits associated with the lagoons and beach sands.

The soil survey of Tongatapu was carried out by the New Zealand Soil Bureau in 1968 (Gibbs, 1968), and a soil map of the island was produced at scale 1: 100,000 (Fig. 3). The more detailed soil map at scale 1: 25,000 referred to above could not be found. Six main soil series (and various slope and gravel phases which are not taken into consideration here) have been recognized (Gibbs, 1976; Orbell, 1993).

Lapaha series (*local name kelekeleumea*) occur on the eastern part of Tongatapu on flat to rolling slopes, surrounding the Vaini series. These are well-drained soils, developed on older volcanic ash with a local thin surface layer of younger ash; the latter is often mixed with the underlying material. Weathering of the older ash is more advanced than in the Vaini or Fahefa soils, and textures are therefore heavier than in the two other soils.

The Lapaha soil profile has a thick, dark, friable to slightly sticky clay topsoil with a fine to medium-sized crumb structure. Below 30cm there is a change towards a brown to yellowish brown, firm, very sticky clay, with blocky aggregates coated with dark brown clay. Few soft black or yellow nodules and pieces of coral occur in the profiles. The massive coral limestone is commonly found between 75cm and 1m from the surface.

Lapaha soils have good physical properties. They have a slight limitation of drying out at times when rainfall is low. Because of their high clay content, the use of farm machinery should be avoided when the soil is too wet. With adequate fertilizers they are suitable for a wide range of crops.

Analytical examination (Table 4) of this soil shows an almost neutral pH, high cation exchange capacity (CE) and base saturation (BS). Compared to Vaini series (see below) the Lapaha soils have slightly higher contents of carbon and nitrogen, while overall values of exchangeable calcium, exchangeable potassium, phosphate retention are slightly lower than those for Vaini soils. The total clay content ranges from 70 to 86% and is dominated by halloysite. There is a notable absence of glass in the sand fraction.

The ***Vaini series*** (*kelekelefatu*) occupy the central and eastern parts of the island; they are the most extensive soil unit of Tongatapu. It is the thickness of the younger ash (Vaini ash) that separates the Vaini (> 40 cm of younger ash) from the Lapaha soils. Formed in the younger tephra these soils are less clayey and better structured than the Lapaha soils, and dry out only slightly in periods of low rainfall.

These are well-drained soils with a thick, dark, friable clay topsoil without noticeable lapilli overlying at 30-35cm depth a dark reddish brown clayey subsoil, firm, sticky, with blocky clay-coated aggregates, and with many weathered lapilli. Both the top- and subsoil contain nodules of black manganese concretions, and small grains of weathering ash. Underlying these reddish brown clays there is a brown heavy clay which rests on coral limestone at depths between 1 and 5m from the surface.

Analytical data for these soils (Table 4) indicate: (1) almost neutral pH values (6.4 to 7.6); (2) high base saturation (80-100%) dominated by exchangeable calcium (30-40 me); (3) high values for exchangeable potassium (1-3 me) and phosphate retention (50-80 %); (4) high contents of total iron, aluminium, copper, cobalt and other metals; and (5) medium total nitrogen in the topsoil (0.4%) decreasing to less than 0.2% in the subsoil. The clay fraction, dominated by halloysite, varies between 50-60% but, in contrast to Lapaha soils, still contains hyperstene, feldspars and glass in the sand fraction. These analyses confirm the assessment of Vaini soils as nutrient rich soils.

Fahefa series (also known as *kelekelefatu* or fertile soils) are found in the western part of the island. They are well drained, deep, loamy textured and well structured soils developed over deep deposits (more than 1m) of younger ash, overlying the older tephra. They have a thick, dark, friable clayey topsoil with a few lapilli (volcanic stones) over a more compact, brownish clay subsoil. These are versatile soils which are capable of producing sustained high yields for a wide range of crops if soil fertility is maintained. Besides nitrogen, they require a complete NPK dressing and some additional sulphur for intensive long-term cultivation.

In the semi-detailed soil survey at scale 1: 25,000 the Lapaha, Vaini and Fahefa series are subdivided into flat and rolling phases depending on the dominant slope. Both phases differ in terms of land capability and suitability, susceptibility to erosion and runoff, and in their management.

Fatai series are derived from volcanic ash which has been washed into slight depressions in the lowest part of the landscape, especially near the northwest coast of the island. They are poorly drained and include often a compact hard subsoil which makes them unsuitable for deep rooting crops or crops which do not tolerate standing water for lengthy periods.

Sopu series are found in low wet areas of small bays and tidal marches, and old lagoon sediments. They are very poorly drained, often with a saline groundwater table, and include areas with very acid soils. They are subdivided on the basis of texture: sandy and sandy loam. Sopu loam has often moderate to high organic matter contents, reaching almost a peat status in some places, and are usually covered by a mangrove vegetation. Their crop suitability is low.

Nuku'alofa series are young and shallow soils developed from accumulated coral sands just behind the active beach along the northern coast of Tongatapu. These soils are subdivided on the basis of texture into sandy and sandy loams. Both soils drain rapidly, but the sandy loam retains more moisture and is less liable to organic matter depletion than the sandy soils. Both soils have an alkaline reaction and low levels of available phosphorus and potassium.

Dept (cm)	Clay %	Silt %	Sand %	pH H_2O	CE * me	BS %	Ca* exch	K* exch	C %	N %	C/N
Vaini Clay											
0-13	53.1	20.3	19.2	7.6	57.4	87	33.8	3.1	4.9	0.42	12
13-28	53.8	20.0	18.4	7.2	50.3	94	33.4	1.7	2.5	0.20	12
28-41	57.6	18.4	16.6	6.4	57.0	88	34.6	1.8	2.3	0.17	14
61-76	39.8	23.0	16.3	6.7	55.9	81	30.9	1.0	0.8	0.07	11
Lapaha Clay											
0-13	68.0	8.6	11.3	7.7	55.6	95	43.5	2.3	5.8	0.59	10
13-30	71.5	6.6	10.6	7.7	42.4	92	31.4	1.4	2.7	0.23	12
33-51	79.6	2.7	4.8	6.8	36.3	80	21.0	1.6	1.3	0.10	13
58-76	82.7	2.1	3.1	6.8	37.6	69	18.7	0.0	1.1	0.09	12
Nku'alofa Sand											
0-20	-	-	-	7.9	-	-	-	-	8.5	0.85	10
20-30	-	-	-	8.3	-	-	-	-	2.9	0.35	8

* Cation exchange (CE), exchangeable Ca and K: in me/100g of soil.

Table 4: Analytical data from three representative soils in Tongatapu Island (Gibbs, 1976).

Soils of other islands - It could be concluded from literature that the main outer islands have a soil map at scale 1: 25,000. The broad description of these soils is given by Orbell (1993). 'Eua contains 17 soil units, The Vava'u group has 9, and the Ha'apai group has 19. The maps seem not to be available in the country.

Soil chemical properties - In general, chemical properties of the upper soil horizons are relatively uniform, particularly in volcanic ash soils. This means that variations in organic matter (OM), nitrogen (N), phosphorus (P) and potassium (K) contents are more likely to reflect past management practices such as cropping, length and importance of fallow, burning, and the presence of old village sites, rather than inherent differences in natural soil properties.

Most volcanic ash soils in Tonga have a pH between 6.5 and 7.5 which is ideal for crop growth. Exceptions are some mangrove soils (Sopu series) which develop sulphuric acid and low pH around 3.5, or corral soils with free carbonates and alkaline reaction (pH 8.0 or more).

Topsoil organic matter is high (> 5%) under forest or at the end of a long fallow period, but decreases rapidly after continuous cropping for several years. Shortening the fallow period and/or longer periods of continuous cropping will thus lead to a decline of OM in the long run. Nitrogen is usually the main limiting nutrient, with deficiencies of phosphorus and potassium in soils depleted by intensive cropping and burning. As a high proportion of these elements is present in an organic form, the proper management of soil organic matter is crucial in these soils.

Soil physical properties - The soil physical properties like soil texture, density, porosity and water retention capacity determine the plant-available water in the root zone, soil aeration (important for soil-plant gas exchange), ease of root penetration, and the amount of soil which can be explored by roots for nutrient and water uptake.

In general, the volcanic soils of Tonga have medium to high clay (40-60%) contents in top soils and very high (>60%) subsoil values, particularly where the older, more weathered volcanic ash layer forms part of the subsoil. On top of this very clayey layer percolating water might temporarily stagnate and create local water logging conditions for roots. The high clay content of the surface layer makes them also quite sticky and plastic when wet. Tillage operations should therefore be avoided in wet soils in order to prevent structural deterioration.

Infiltration tests, reported by Mafi and Crennan (2007), have indicated that, despite their high clay content the volcanic ash soils of Tongatapu are quite permeable. This is the reason why there is almost no surface run-off except in local areas of compacted soils, or on slopes (rolling phases of Lapaha, Vaini and Fahefa series). On sloping islands (like 'Eua for example) run-off is a problem, particularly if the land surface is not covered by vegetation, or after deforestation.

Soil water retention in Tongan soils is medium to high (approximately 20%) in the surface layers but decreases rapidly with depth (13 - 15%). This is largely due to decreasing organic matter content and compaction. Hence, it is important that soil organic matter levels and topsoil structure are well managed, and that topsoil loss through erosion is prevented as otherwise the profile might become more prone to drought.

Soil mineralogical properties - The volcanic ash soils have a high to very high clay content dominated (> 95%) by halloysite, which gives these soils a good and relatively stable structure. Iron oxide minerals (mainly haematite or goethite) are responsible for their red or rusty colour, the formation of pseudo-sands and a better water permeability; they affect also the soil retention of phosphate and sulphate ions. It is likely that the differences in structural and physical properties of Tongan soils are closely related to the amount of clay present and to the nature and content (1-5%) of the iron oxide minerals. Soils developed on other parent materials have a mineralogy dominated by montmorillonite or calcite.

3.4. Water

Despite a high rainfall, water is a relatively limited resource in Tonga. The country does not have surface water apart from a few salty lakes on the islands of Tofua and Niuafo'ou. The freshwater resources of Tonga consist mainly of groundwater in the form of freshwater lenses within the porous limestone substrate. Freshwater lenses form on top of seawater in many of the islands due to the difference in density of the two fluids. Surface water resources are only evident on some of the high volcanic and mixed-geology islands in the form of springs and lakes. On the island of 'Eua potable water is collected from cave systems.

Rainwater harvesting systems are a complementary freshwater resource and an essential source of potable water on many other islands. On some of the smaller islands in the Ha'apai and Vava'u groups they are the only source of drinking water. On Tongatapu and Vava'u water supply is not a top priority, because it is rarely in short supply. On other smaller isles and atolls water is highly valued, and local communities often experience limited supply or poor quality.

Water for **domestic use** in urban areas is obtained from groundwater. It is chemically and bacteriologically controlled and piped by the Tonga Water Board in urban areas of Nuku'alofa (Tongatapu), Neiafu (Vava'u) and Pangai-Hihifo (Ha'apai), and in parts of 'Eua. Many rural villages have their own reticulated water system administered by water committees. Most of this water is metered, and extraction amounts are known. The 1996 census indicated that some 84% of all households in Tonga have access to piped water supply, approximately 58% have their own water tank, and 2% have their own well.

There are actually no functioning desalinisation systems in Tonga. A desalinisation plant was provided to one of the islands of Ha'apai group by the Japanese Government during the late 1980s but no provision was made for running costs (Mafi and Crennan, 2007).

Use of water for **agricultural and livestock purposes** is not recorded. Small irrigation systems operated from local boreholes are in use by some commercial farmers. Domestic grey water is commonly re-used for livestock, especially pigs. It is not known how many bores are operating in the country, and it is not known what volume is being extracted. Though there is no direct danger for an imminent shortage the unlimited extraction of groundwater from unregistered and uncontrolled boreholes might create problems in the future.

There is no reticulate sewerage system in Tonga. **Wastewater** is managed by on-site systems, with supervision by the Ministry of Health, when resources permit. In this respect wastewater management is in the hands of the community. Poorly constructed or inappropriate sanitation systems are common, resulting in the potential spread of pathogens and nutrients in the environment, including ingress to groundwater.

3.5. Vegetation, Land Cover and Land Use

Most of the natural vegetation of Tonga has disappeared. The country has been settled since the first Millenium, and during 2000 years of occupation, with a shifting subsistence agriculture, the native vegetation has been greatly modified. Only on the steeper and most remote sites can it be considered to be almost pristine**.**

There is a wide variety of vegetation types throughout Tonga. A description of the various types of vegetation is given in ESCAP (1990) and the Tonga Biodiversity Stocktaking report (Prescott and Folaumoetu'i, 2004). Indigenous vegetation includes a variety of root crops, fruit trees such as mango's, tava, and a variety of citrus, and native vegetables and grasses. In the settled areas of the four Island Groups, much of the native vegetation has been cleared for coconut plantations, home gardens, villages and commercial crops. A significant percentage of the country is now under coconut in Panicum grassland.

Figure 4 displays the land cover map of Tongatapu island. It illustrates that the dominant land use type is made up of cropland, grassland and scrubland (or forest re-growth as part of the fallow period). There are a few isolated patches of woodland, spread over the island. The built-up area covers the city of Nuku'alofa and some smaller settlements around the central lagoon area (Ha'atelho, Folaha, Longoteme, Vaini and Mu'a, the old capital). Kolovai and Kalonga are the most important villages on the northwest and northeast coasts. Mangroves form a narrow strip along the edges of the central lagoon as well the marshy area north of Nuku'alofa towards Mulfula Point.

3.5.1. Agriculture

Tonga's economy is largely agriculture-based and it grows mostly root crops (yam, taro, sweet potatoes, cassava and giant taro) principally for domestic consumption; squash pumpkin, vanilla, and kava for exports; water melons and fruit trees including banana, plantain and papaya; and fibre crops such as *Pandanus* and paper mulberry for handicrafts.

Agricultural production is still the predominant economic activity, with a contribution of more than 40% in the 1980s and early 1990s, and some 30% at present. The agricultural sector remains important as a source of domestic food supply, employment, cash income, foreign exchange earnings, and raw materials for processing and handicrafts. A significant percentage of economically active Tongans (58.4%) rely on primary food production for their livelihood, though as a result of urban drift, this figure is rapidly changing.

Rich volcanic soils on most of the islands provide a good base for farming. Agriculture is largely rainfall-dependent and is highly vulnerable to drought. The poor squash yield in 1998 and the food scarcity experienced during that same period in Ha'apai are exemplary to this problem. Irrigation from groundwater is not commonly practiced, although some experimentation has occurred by the larger squash exporters. The most significant impact modern agriculture has had on land use is in the modification of the farming system, the introduction of farm machinery, and the application of agrochemicals (fertilisers and pesticides in particular).

Farming Systems - The traditional Tongan farming system is based on subsistence cropping dominated by root crops; still these crops are occupying 2/3 of all agricultural land in production. This involves a slash and burn of the forest vegetation followed by 3-4 year cropping cycle. The rotation usually starts with the most highly valued crop, yams, inter-planted with taro, plantains and bananas to optimise yield, spread risks and provide food over a long period of time. Following the harvest of these early crops taro, sweet potatoes and various types of vegetables are planted. Cassava (the crop with the least value) is grown as the last crop in the cycle before the land is left to regenerate in a long fallow.

It was not until the 1950s and 1960s that Tonga moved from subsistence to an increasingly cash-oriented farming system. That was when bananas, pineapples, watermelons and vegetables were exported to the New Zealand markets. This change was accompanied by strict quality control measures on all agricultural products, and by the introduction of pesticides and other agrochemicals to control pests and diseases. High production levels for commercial farming required also the reduction of bush fallow and the use of increasing demands of mineral fertilisers. Subsequently, environmental hazards and risks became a national issue.

In a traditional cropping system the production of root crops is alternated with a bush fallow of a few years to allow regeneration of natural nutrients in the root zone. In this traditional system the maintenance of a high content of organic matter is a key element. Under an increasing population and land pressure the length of the fallow is reduced and, in particular in commercial farming, the OM stock is rapidly depleted. This problem can now to some extent be solved by the introduction of *mucuna beans* in the rotation. Though its long-term effects are not yet well known, *mucuna* has the advantage of being a leguminous catching nitrogen from the air, while protecting the surface against erosion and producing high amounts of organic material.

The local system of shifting cultivation has been successful in meeting local food supplies and providing a small export surplus of copra and bananas as long as land was plentiful available. But the system is becoming less and less adequate in a situation of increasing population, lack of farmers and limited acreage of cultivated land. If the Kingdom wants to remain self-sufficient in primary production a more efficient farming system is needed. For the proper development of such a system, scientific information on the properties and needs of the soils and crops is essential.

In recent years there has been some promotion of organic farming. Though this is, particularly from the environmental point of view, an interesting alternative it should be noted that this system is easily applicable on smaller farm units (horticulture and small-scale gardening), but is much more difficult at a larger scale because under tropical climatic conditions organic material rapidly deteriorates.

Local Food Crop Production - The traditional Tongan diet is based on starch food. Therefore, and despite many other high-value crops can be grown in the country, root crops dominate the cropping system. It is only since the late 1980s that some commercial crops for export to Japan and Korea, like vanilla, watermelon, squash-pumpkin and Tongan taro have started to take more land for commercial crop production.

Yam **(*Discorea spp*)** is the most valued of all edible tuber crops and is considered the best tasting of all root crops. Asiatic varieties grown in Tonga are succulent and less toxic than African ones. Traditionally, yam has also the highest social value, and is the first crop reserved for presentation to royalty and nobility; and for ceremonial functions and feasts. Six species are found in Tonga, three of which are effectively cultivated. The variety *D. rotundata* or White Guinea Yam (*lose* in Tongan) is a 8-months variety, adapted to less fertile soils, and immune to anthracnose disease.

The other three important root crops are taro, cassava and sweet potato. There are three main varietes of taro cultivated in the country. ***Common Taro*** **(*Colocasia esculenta)*** or *Talo Tonga* is grown in the high rainfall areas; it is cultivated both for local consumption and for export. ***American Taro*** **(*Xanthosoma sagittifolium)*** or *Talo Futuna* is more tolerant to drought. ***Giant Taro*** **(*Alocasia macrorrhiza*)** or *kape* is the most esteemed taro variety and is therefore second to yam in its role for presentation to nobility.

Cassava **(*Manihot esculenta*)** or *manioké* is the most widely consumed edible root crop in the country. It requires less fertile soils than yams and is therefore often planted as the last crop in the rotation, whereby it can remain for a long time in the ground. ***Sweet potato*** **(*Ipomea batatas*)** or *kumula* is second to cassava in consumable staple foods in Tonga. It has gained great importance over the years, mainly because it has a short growing period, is rather tolerant to drought, and is both a food and a cash crop.

Irish potato **(*Solanum tuberosum*)** or *pateta* is still rarely cultivated, but shows good perspectives to meet a growing local market. The crop thrives well in the cooler season but requires special storage facilities under the humid and warm climate of Tonga.

The Kingdom of Tonga holds a wide variety of fruit trees but, because of an obvious lack of selection and proper phyto-pharmaceutical treatment, its products can hardly meet the export quality requirements imposed by New Zealand, Australia and the US to where the goods are exported. Common fruit tree crops are: ***Mango*** **(*Magnifera indica*)** of which the country holds 15 different varieties, ***Pacific Litchi*** **(*Pometia pinnata*)** or *tava*, ***Citrus spp***. including pomelo, sweet orange and mandarins/ tangerines, ***Malay apple*** **(*Syzygium malaccense*)** or *fekika*. All these fruit trees suffer from fungus and virus diseases, are affected by fruit flies and are therefore a core reason for quarantine protocols.

The most important tree of the country, also considered the tree of life because of its multifunctional uses, is ***Coconut (Cocos nucifera*)**, or *niu* in Tongan. After the decline of the copra industry the importance of the tree declined, despite that senile coconuts still provide a valuable timber. The Rhinoceros beetle (*Oryctus rhinoceros*) which is a well-known pest in all palm groves worldwide is also present in Tonga.

Breadfruit, papaya or pawpaw, soursop, custard apple and avocado are widespread throughout the country. They are not properly cultivated, but grow naturally throughout. The most important local fruits are pineapple, passiflora, banana and especially watermelon, which is still a cash crop for the local market. The crop has also a long-standing export reputation.

Commercial Crop Production - Agriculture has also consistently been the main foreign currency earner over the years. Between 1960 and 1970 the main agricultural export crops had been copra and banana. With the defunct of the banana project and the decline of copra, vanilla became the main export crop, followed from the late 1980s onwards by squash and taro. Yams are exported in small amounts to the Tongan expatriate communities in New Zealand and Australia. In recent years also nonu is exported.

Tonga is able to grow a wide variety of vegetables, including: various types of beans, beetroot, cabbage, capsicum, carrot, cauliflower, cucumber, eggplant, lettuce, okra, onion, radish, sweet corn, tomato. Although for the European-type of vegetables the growing conditions are not optimal, they might supply reasonably well the local markets (mainly to reduce the import of these goods) if properly managed and even foreign markets when introduced as off-season crops.

By far the most important export product for the moment are ***pumpkins-squash (Cucurbita max.)*** for which there is a high demand from Korea and Japan. Immature fruits are eaten as fresh vegetable, either stewed, boiled or fried. Mature fruits are used for baking, making jams or pies. They can also be used for feeding pigs.

Pumpkins can be grown in almost all types of soils, provided they are well drained and of good fertility. They prefer soils rich in organic material. They are harvested after 3-5 months. The most important problem for this produce in Tonga is to meet the required export quota.

Vanilla (Vanilla fragrans) is currently cultivated at small scale in Tonga. It grows as a shadow plant and a tree-climber in a hot and humid environment with frequent but non-excessive rain. It thrives well in humus-rich soils. The production and treatment is rather labour-intensive and requires a good knowledge of the hand pollination technique. The first harvest starts in the third year of growth and extends over 5-6 years or more. Yield levels are in the order of 1000-1400kg green vanilla /ha for well-maintained plantations.

Coffee (Coffea Canephora) is a potential cash crop for the local market and for export. The variety grown is Robusta. A coffee plantation was visited on the island of Tongatapu. Growing conditions are good though soil pH might be a bit too high and care must be taken to avoid soil compaction from mechanical soil treatment.

Kava (Piper Methysticum) is a bushy shrub, 2-3m high. It is traditional crop and the basis for a national drink in Polynesia. Nowadays, it has developed as an export product, mainly to the expatriate communities of Polynesian origin throughout Oceania. It is a narcotic and hypnotic drink, made from the thick, knotty, greyish-green roots, fermented in water. The country holds several varieties and the crop is often integrated at the end of the traditional crop cycle.

Fresh agricultural products are sold locally in market centres, or stalls on the roadside. Daily supply is reliable unless production is interrupted by natural disasters. The price of the local product is not regulated which means that a sharp rise in price can occur when supply is limited (out of season, cyclone). These prices are sometimes beyond the buying capacity of low to medium earners.

3.5.2. Livestock

As the average Tongan diet of starch food is poor in proteins, it needs to be supplemented by meat and/or fish products. Fish is widely available, but most meat is imported.

There are a few cattle farms in Tongatapu, but little information on this type of land use could be collected. FAO is currently investigating the possibility to raise sheep in Tonga and, thus, to reduce the quite large importation of mutton in the country.

There exist also a few chicken farms in Tongatapu and the production of chicken meat appears to be possible, but the economic cost of the imported feed is still a burden. In this respect the possibility to grow maize, and thus to produce most of the chicken feed in Tonga itself, should be explored. Growth conditions for maize in terms of climate and soils are anyhow favourable. A research project on the adaptability of best suited varieties and on their position in the rotation is under way.

The raising of pigs is a common feature in rural areas. They are fed on kitchen refuse and coconut residues. Because they are usually free roaming they do often a lot of damage to crops. In sloping terrain they might initiate soil erosion.

3.5.3. Forestry

All islands in the Kingdom were originally covered with a dense tropical rainforest. Today, there are only few remaining natural forests in the country. They are limited in extent, being mainly restricted to very steep, remote, or otherwise inaccessible areas, to coastal littoral areas and swamps, or to mangrove swamps. Most of Tonga's forested land is situated in the less populated outer islands.

The area under indigenous natural forest is estimated between 4,000 and 8,000ha, depending on the source and on the definition of what is a forest. In the densely populated island of Tongatapu the natural forest area is limited to 862ha. In the much less populated island of 'Eua approximately 43% of the total land area (8,900ha) is still under forest. A relative important unit of exotic tree plantation of 300ha exists in 'Eua.

Coconuts are encountered everywhere and, together with the remnants of native forests, form the bulk of so-called anthropogene forests. They grow as individual stands in agricultural land or as established plantations over larger areas. The area covered by coconut palms is estimated at 35,347ha or approximately 50% of the total land area.

Economic value of forests - One of the many functions served by remaining natural forest fragments is to provide local people with firewood, edible plants, plants used for medicinal and cultural purposes, carving materials, etc. Populations of high-value species have declined and, consequently, commercial timber is nowadays hard to find. Forest replanting is needed either in pure stands or as part of agro-forestry, strip cropping or other farming systems.

The demand for fuel wood in Tongatapu island alone is estimated at 100,000 tonnes per year (equivalent to 200,000m^3 of fresh wood), with 70% for domestic use. The main source for this are large hardwood trees and shrubs on tax allotments. An increasing portion is shipped from 'Eua and other nearby islands.

It is estimated that about 700m^3 of plantation logs and 500m^3 of coconut logs are tilled each year, most of which are used locally. In 2006 the country still imported 5,240m^2 of sawn timber and 19,200m³ of wood for squash boxes, for a total value of T$ 4,674,000. There is thus considerable scope for the local industry to cover part of these imports.

Environmental value of forests - Forests play a major role in the conservation of terrestrial biodiversity. They assist in the conservation of natural habitats and provide good protection against soil erosion. Coastal forest strips prevent shoreline erosion and protect inland agricultural and inhabited areas against strong winds and salt-spray. Unfortunately, many of those strips have been seriously reduced in extent, especially in Tongatapu. Some consider therefore the remaining forests to be unimportant because they are only secondary, small in extent, and more disturbed than the remaining primary forests on the outer islands. However, these fragments are the main forest areas with which many of Tonga's people have regular contact, and this contact is essential because of the importance of forest products in Tongan culture and underpins the support for protection of high-value forests elsewhere in the Kingdom.

Forest degradation and deforestation in Tonga are relatively high, mainly because of easy access to logging and clearing of forest land for residential, agricultural or other uses. Due to limited availability of land, mangrove areas in Tongatapu and Vava'u are cleared for residential purposes. Small-scale degradation of forest land for firewood exploitation and other small-scale uses in rural areas are not registered. The transformation of forest and tree cover to agricultural land, is relatively easy as well because of the lack of regulations in the lease contracts. In fact, the Government has no legal elements to stop small-scale tree cutting, unless through the application of an Environmental Impact Assessment (EIA) procedure. Up till now no such procedure has been carried out. Prescott and Folaumoetu'i (2004) have estimated the rate of forest transformation to (mainly) commercial cropland at 600 ha per annum between 1980 and 1995.

Timber exploitation in the country is facilitated because of lack of enforcement of the proper legislation. No permits are required for logging trees on the own property and, thus, can informal arrangements for logging on "someone else's land" easily be obtained. Likewise is logging in government land (for example on coastal areas) done without permit because of the lack of enforcement of regulations.

To date, most indigenous forests are almost completely exhausted. About 80% of the current domestic cuts (1,700m³ per year) is from coconut palm logs. This means that 72,500 coconut palms have been cut annually throughout the Kingdom over the last 30 years. Replacement plantings have taken place at a rate of about 25,000 new palms per year for the last 15 years. It is estimated that 90% of local timber production are used locally, mainly for house framing.

Finally, it should be noted that there is little esteem for the conservation of forests as domestic animals (pigs, dogs, goats), from which it is known that they destroy easily new shouts, can be freely ranged.

Reforestation - Apart from the 'Eua Forest Plantation the rate of tree planting on private farm land is low. Tonga's Forest Act (1993), actually under revision, allows the Government to set up forest reserves and control forest use, with the Forestry Division of MAFF being appointed as the main facilitator of the national tree planting efforts, including the replanting of coconut palms. The Forest Division operates nurseries all over the country and coordinates tree planting activities as well as awareness creation and community-based tree planting activities.

Forests types - In Tonga three major types of forests can be distinguished: interior forests, coastal forests and coastal swamp forests.

Interior Forests have a very variable composition. They consist for a large part of (former) coconut plantations mixed with shrubs, grassland and cropland; they include also forest regrowth (as a result of abandoned fallow land) and remnants of indigenous forests (Figure 4). Similar remnants can also be found in the ‘Eua and Talau National Parks.

There are also 510ha of commercial timber plantations in ‘Eua, planted mainly with Caribbean pine, red cedar, mahogany, kauri and eucalyptus spp. An additional 50ha of plantation forest, mainly in ‘Eua, is privately owned.

Coastal Littoral Forests are found on sandy or rocky soils in areas exposed to strong winds and salt sprays. A salt-tolerant vegetation predominates. This vegetation covers mostly areas of unsuitable land for agriculture. It provides nevertheless a valuable source in terms of timber, medicinal plants, wood for carving, and fuel wood. It plays a vital role in protecting inland crops from salt spray and storm-wind damage, as well as in coastal erosion protection.

Swamp forest is primarily found on the low lying areas of Tongatapu’s north coast, where soils are mostly hydromorphic and/or inundated at times of excessive rain and sea-water intrusions. It is an open to semi-closed forest with an under-story of salt-tolerant shrubs. It holds soils with a high organic matter content and poor drainage.

Mangrove swamps consist of trees, mainly dominated by *Rhizophora spp.*, growing in salt or brackish water on a muddy substratum below the limits of high tide. The total mangrove area for Tonga is estimated at approximately 1000ha, widely distributed throughout the country, especially in the Tongatapu and Vava’u island groups. The largest extension of them occur in the Funga’uta Lagoon near Nuku’alofa, where they cover some 45km of the total 58km lagoon coastline.

The mangrove ecosystem is protected under the Birds and Fish Preservation Act 1974, and the cutting of mangrove around the Funga’uta and Fangakakou Lagoons is totally prohibited under this act. The effectiveness of this legislation is, however, small as illegal cutting, mainly for residential settlements and land development, is still a common practice.

Mangroves have no direct agricultural value, but may provide excellent fuel wood, if properly managed. Mangrove ecosystems assist in the stabilisation and expansion of coastal wetlands. They also provide enormous and often under-valued coastal protection benefits against storm surges, erosion, etc. The roots of mangrove plants are a nearly impenetrable barrier, and so provide a safe environment for organisms around the trees. They shelter many species of crabs (with high economic value) and provide shelter for sponges, oysters, snails. They also serve as breeding grounds for prawns and commercially valuable fishes.

3.6. Population

Tonga’s total population counts for 97,784 (Census of 1996), and is estimated to have reached between 101,000 and 103,000 in 2006. The projections for 2026 forecast a net annual population growth of approximately 0.5% to reach a figure just over 105,000. The main reason for this relatively small increase is that since the early 1980s there has been a steady 2% rate of outward migration of Tongan citizens overseas mainly in search of employment.

Tongatapu is the most densely inhabited island, with a population of almost 67,000 (69% of the total). The outer islands are much less densely populated: 15,715 inhabitants (16%) for Vava'u, 8138 (8%) for Ha'apai, 4934 (5%) for 'Eua, and 2018 (2%) for the Niuas.

There has been a gradual population increase in the Kingdom from 77,429 inhabitants in 1956-66 to 97,784 in 1986-96 and 103,000 in 2006. Average population growth over the period 1986-1996 was only 0.3% per year. This figure and the regional distribution masks, however, the high degree of international out-migration of young Tongans in search for work, and the continuous in-migration from the outer inlands towards Tongatapu. The latter island as a whole registered a 11,251 net population increase in 1986-96; most of the migrants settled in and around Nuku'Alofa.

This rural inland migration towards Nuku'Alofa is made up of 21% of people coming from rural areas in Tongatapu itself, 26% of Vava'u and 31% Hapa'a. Reasons for this rural drift are linked to the search for employment and education since Nuku'Alofa is the centre of employment and education of the country. Population projections forecast that this trend will be maintained for at least the next 50 years.

Life expectancy is high: 69.8 years for males and 71.8 for females. Tonga has an exceptional high level of literacy (98.5%). Primary education is universal, and most students attend the mid-secondary school level as well.

3.7. Economy

External payment balance - Tonga's economy, as a small island developing state was typically structured around a large public sector with dependence on remittances and foreign aid. Between 1973 and 1995 the economy grew at the annual average rate of 1.8%, with per capita income growth at 1.2%. The real GDP grew at the annual rate of 2.2% from 1994 till 2001, but in this period growth rates varied from minus 0.1% to 6.2%. The primary sector grew at just 0.4%; the secondary sector at 4.6%; and the tertiary sector at 3.5%. The government administration and community services sectors were the main contributors to growth, and in 1996, full-time government workers accounted for 39% of the economy, with 13,318 Tongan employees paid in cash.

The inflation rate between 1985 and 2001 varied by 6.4%. It was below 3% between 1996 and 1998, but subsequently accelerated to over 6% in 2001 and 10% in early 2002 as a result of expansionary macro-economic policies and substantial currency depreciation, drought and cyclone damage, and higher world prices.

In FY 2001 a 20% civil service wage rise and below budget non-tax revenue collection increased the current budget deficit to almost 0.5% of GDP. The overall budget deficit was 2.6% of GDP and was financed by the domestic banking system, causing a rise in public domestic debt outstanding to 55%. In mid-2001, the external debt was US$ 63.6 Million (44.7% of GDP).

The domestic currency, the pa'anga, is pegged to the currencies of Australia, New Zealand, the United States and Japan. During the fiscal period 1991-2001, the pa'anga was devaluated by 22% in nominal and 10% in real effective terms. The currency devaluation followed largely the 1998 private sector credit expansion and subsequent loss of foreign reserves. The exchange rate mid 2008 is at 1.75 - 1.85 T$ for 1 US$.

A reduction in the public sector wage bill was considered necessary to allow for more expenditure on operation and maintenance. The downsizing of the public sector to increase efficiency was supported by various donor agencies, and in 2006, some 1000 public servants accepted an offer of redundancy packages. The private sector and the community initially benefited from this operation, but by 2007, extended families who were previously dependent on the civil servant's wages were forced to look for support elsewhere. The riots in November 2006 resulted, however, in the closure of many businesses, the withdrawal of foreign investment, further unemployment and subsequent loss of consumption and income tax revenue. The government now needs to raise funds for the reconstruction of the Nuku'alofa central business district. Donor agencies have offered technical advice to the Government and are pooling a fund for loans to affected business.

An important factor in the external payment balance is the high overseas remittances which, to date, still account for almost 40% of the country's foreign exchange earnings. Therefore, every attempt must be made to lessen reliance on external factors over which the country has no control, e.g. reduce the import of goods that can be produced locally, and promote the export of cash crops.

Foreign Trade Balance Today - The statistical data from the foreign trade report for 2007 (Statistics Division, Min. of Finance, 2008) indicate that, in terms of value, Tonga is currently importing almost 20 times more than it exports : 281,031,541 T$ import against 15,768,569 T$ export. In 2000, 2001 and 2002 the import was still low, but amounted rapidly to 4,202,555 T$, 4,241,452 T$ and 6,650,947 T$ respectively. This is an evolution which can not last for long, even if remittances from overseas do to some extent balance this deficit.

The major components in the list of imported commodities are: (1) prepared foodstuffs, beverages and tobacco for an amount of 43,191,653 T$; (2) live animals and animal products for an equivalent of 30,141,257 T$; (3) vegetable products, wood and wooden articles, and wood pulp and paper products for more than 8.5 million T$ each.

Many of these imported commodities can be produced, partly or in total, in the country itself through a more intensive and more efficient land use. This refers in particular to the compensation for bovine and poultry meat imports (cost 765,324 T$ and 9,213,649 T$ respectively) and for mutton import (cost 11,403,141 T$), while there are also perspectives for a consistent export of agricultural goods, and for local timber production to compensate for the imports of wood products.

Food production and import have for many years been a concern in Tonga. In 1999 the import of this commodity was over T$ 20 Million per annum and accounted already for more than the total export. Nowadays, it is more than five times this amount, while the total population has hardly increased. Meat accounts for most of the food imports, particularly mutton flaps (off-cuts containing high concentrations of saturated fats), followed by cereal products, dairy products and sugar and confectionary.

It appears that Tonga does not import according to food needs but rather more because of luxury demands. The widespread consumption of these products is also a likely contributor to national health problems such as heart disease, obesity, and diabetes. Despite an abundance of local fresh fruit such as bananas and papaya, children are commonly given money for confectionary as their school lunch.

The ratio of the value of agricultural exports to the value of food imports is probably the most useful indicator of Tongan agricultural performance over time. The ratio had further declined from 0.5 in 1986 to 0.27 in 1988, but picked up after that and peaked at 0.86 in 1993, and thereafter declined to a low of 0.23 in 1998 before picking up in 1999. The recovery of the ratio after 1987 can be explained by the introduction of squash pumpkin to the export. After 1989, squash became the major exporter for Tonga with an increasing contribution to the economy. The low ratio in 1998 was caused by the poor squash crop because of the drought and the very low contribution by vanilla to the export economy that year. Kava export was second to squash pumpkin in 1998 contributing over T$ 2 million. If the country should import food more in accordance with food needs, and crop production in Tonga should be intensified and in line with its production potential then the ratio would be above one.

3.8. Land Tenure

There is no specific land policy in Tonga, but the Land Act (1988) defines the nature of the land law, modalities for access to land, land registration in terms of ownership and lease arrangements, and all other notions on which decisions about land allocations are based. The Land Act overrides all other laws in terms of land issues, but is difficult to implement because it interacts with other (and sometimes controversial) laws, has no proper regulations for enforcement, and has inadequate provision and capacity for enforcement.

Land tenure - The key elements in Tonga's land legislation are the traditional land tenure system and the fundamental right of each male Tongan of access to land. The King is the owner of all land in Tonga. The King and the Royal Family retain ownership of the *King's Estate* and the *Royal Family Estate*, and these lands are not available for subdivision or leasing. *Nobles Estates* are derived from a hereditary grant of land from the King. Land in the nobles' estates can be subdivided, allocated and leased. Finally, there exist also *Crown/ Government Estates* where land acquired from the King is used for public purposes like roads, parks, cemeteries, schools, government buildings, etc. and coastal land. This is governed by section 138 of the Land Act.

Every male Tongan over the age of 16 years has an entitlement to a Town Allotment and a Tax allotment (corresponding with a piece of land in the rural area) held as a life interest that is passed down through hereditary rules specified in the Land Act. This provision places an obligation and a restriction on the government in terms of land allocation. Due to population growth and land shortage there are, however, many males who are entitled to allotment land but who can no longer be allotted.

Based on the above principles, most farm land in the country is subdivided into so-called Tax Allotments of around 3.33 ha allotted to individuals in accordance with the Land Act. These allotments are subject to substantial constraints. No individual may hold more than one Tax Allotment. The allotment may not be sold, nor may it be subject to any agreement not envisaged in the Land Law. Allotments may be inherited, with succession defined in the Act, and life interests in favour of widows. Allotments may be exchanged and leased, although only for a maximum of 20 years plus one 10 year extension. No individual may be the lessee of more than ten Tax Allotments. The allotment is subject to forfeiture if it is abandoned for a period of more than two years, and the allottee may be subject to ejectment for failure to meet specified rental and cultivation obligations, including in relation to the planting of (200) coconut trees. Both allotment holders and lessees may mortgage their interests to specified lenders on conditions laid down in the law. In the event of default, the lender may take possession and either retain possession for the unexpired term of the mortgage or sublease the land for the unexpired term of the mortgage.

The Land Act provides for the registration of allotments and leases and for compulsory acquisition and compensation, and in its schedules for the forms, fees and charges in relations to actions under the law.

The majority of the Tax Allotments are cultivated in a traditional farming system for local food supply and subsistence of the family. These allotments usually include stands of coconuts, bananas and/or vegetable and root crops grown in a mixed cropping system, either between the coconut palms or in separate small plots. Such individual allotments may be mortgaged or leased.

Many Tax Allotments are, however, not cultivated or are left idle in the sense that crops are not harvested or are overgrown by an extended fallow vegetation or forest re-growth. These plots often belong to absentee Tongans, are not cultivated or are maintained in a poor state by a local care-taker. These allotments are potentially available for lease as well, but are often not leased because the absentee owner would then lose his ability to access the land for the duration of the lease and any extension, and have very little control over the activities of the lessee. A particular concern during the period of rapid growth of squash production has been the lessee’s tendency to fell trees to clear larger working areas for mechanised production, but leading to land mining and degradation.

Secondly, there are understood to be substantial numbers of Tax Allotments effectively in the possession of financial institutions who are holding the allotment or the lease as security for mortgages. The rapid boom in the production of squash, and its substantial reduction afterwards, is responsible for much of this. Most of these foreclosed allotments are understood to remain vacant, notwithstanding that the Land Law allows, for example, for the property to be leased by the foreclosing institution to enable it to recoup its interest.

There are, in addition, very limited numbers of substantially larger farms, extending sometimes up to 50ha and more, obtained through long-term lease contracts. On these, the focus is on large-scale commercial farming for export products (squash mainly) or for cash on the local market (vegetables in particular).

Demand for land - There is demand for leasing of individual Tax Allotments and for other land evidenced by the regular requests to the Department of Surveys regarding the availability of land for leasing for agricultural purposes. The market for land for commercial agricultural purposes has fluctuated substantially over the past couple of decades, depending largely on the demand for land to meet the booming squash market and its quotas. Little or no concrete data is available to enable the nature of the market to be better understood. In general it is reported that people are becoming more aware that their land has value, with elements of markets developing, and banks, insurance companies and business people needing to know values for security and other purposes. While no doubt significant amounts of squash production take place on owner-farmers' own Tax Allotments, there appear to be at least three ways in which this demand for extra land is currently being satisfied, given that sales of land are illegal.

Formal leasing of Tax Allotments from the owner to a farmer on the standard 20 year lease, plus one 10 year extension provided for under the Land Act, is one approach. Given that the area of the Tax Allotment is around 3.33ha, that there is a ceiling on leasing such allotments with no individual allowed to lease in more than 10 allotments, and that administratively such leasing can be both time consuming and costly, this effectively limits the ability of a succesful farmer to scale up a substantial productive area using this approach.

It is understood that a significant element of agreements allowing farmers to undertake squash farming are the subject of more informal access arrangements. While such approaches are not legally provided in the Land Act, and may be of limited use in persuading a bank to provide access to credit (which is generally a requirement for the resource-intensive squash production) they do enable the farmer to access land probably much more cheaply and quickly than through formal leasing.

The third approach is through leasing of noble or, in the past when it was available, government land. The former land, at least, is leasable for periods up to 99 years which may make it substantially more attactive for a successful farmer. This may also provide a comparatively quick and straightforward approach to accessing land for commercial agricultural activity, although it is likely to be a possible solution for a very limited number of farmers, being restricted to those with the right social connections and with more substantial assets.

Regulations and enforcement - Enactment of legislation, whether it be at sector level or in an integrated form, has little meaning if it is not followed by clear rules for its implementation, including the application of penalties. Tonga has no tradition of enforcement of its laws. Despite the good intention of its legislation, law enforcement has been difficult, as resources in terms of finance, tools, equipment and manpower for implementation and enforcement are often not provided.

The Land Act (1988), for example, allows for leases and stipulates their terms and conditions. There are, however, many complaints about their effective implementation. These complaints usually do not refer to the Act as such, but to the interpretation and enforcement of terms and conditions. Section 74 of the Act for example clearly stipulates that each Tax Allotment owner is required to cultivate the land with crops and to plant a number of coconut trees, even under the threat of being brought to court in case of non-compliance to this condition. The enforcement of the Land Law, in general appears to be weak, as witnessed by the informal leasing arrangements that take place outside the Act. Concerns are also expressed by lessees over the standard clauses in the lease terms provided in the Act which indicate that the lease can be effectively cancelled if the tenant does not pay the rent within the stipulated 20 day period. Likewise, tenants may find the statutary inclusion of the provision of a 5 yearly rent review onerous, based on 5% of the assessed land value; particularly where the original rent was agreed outside the formal lease terms, the increase may be substantial.

The enforcement of the Land Law, already noted to be weak, is in part a reflection of this. The Departments responsible for administration, including the registration, survey and valuation, indicated that they have all being substantially downsized as a result of the civil service cuts in 2006. In the case of the Valuation Department, for example, the reduction was from 3 or 4 officers in the period 2000-2002 to the present one officer. The lack of annual reports and statistics has already been commented on, but there appears to be no ongoing management data available on work flows, tasks, etc. to enable any effective management to take place, nor do there appear to be effective targets or reporting mechanisms in place. There are indications that this situation affects morale of staff, while at the same time it may explain why, for example, there are problems in undertaking timely surveys, with reports suggesting that delays may vary from almost negligible to up to 10 years, and why there are governance problems in the form of informal payments to prevent delays in administrative work being done.

3. 9. Land Use Planning

The need for more intensive land use will automatically lead to a greater demand for land. While traditionally land was considered a free gift, it is now desired, and there is competition for it. This competition will occur between various potential users: urban planners, farmers, foresters for various forms of development, and environmentalists for nature conservation and protection. All these users, and the sectors they represent, will have their own reasons for prioritising the land for their own goals and interests, and thus they will develop their own acts and legislation.

To date, there are over 20 sector legislations in the country containing provisions related to the development of land resources. In a number of cases, the objectives and legislation overlap, and conflicts can not be avoided. In order to anticipate such conflicts there is a need for planning the future land use options. This planning should follow an integrated approach whereby strategic options should first be defined in line with the national development strategies, and then subsequently an agreement be reached between different (potential) land users on the most appropriate way to use that land, in particular with respect to the objectives of other sectors.

The Kingdom of Tonga has no established system of planning, not of spatial (or land use) planning, and not at all of coordinated and integrated planning. Currently, there is no umbrella organisation in Tonga for an efficient and integrated land use planning. This is because first, there is no planning concept, second there is no idea of efficient land management, and third there is no political tradition for an integrated approach.

As land use in Tonga is unregulated and unplanned at present, there are substantial conflicts in relation to agricultural land and how it is used, even within the agricultural sector. There are for example concerns in relation to leasing of land for commercial agricultural purposes and their impact on environmental issues. The weakness in the enforcement of the Land Law and the agreement of informal leases outside the provisions of the Act, as already noted, are identified as a source of frustration by the allottees, especially in connection with commercial squash growers. Squash farming in Tonga is a monoculture cropping system with high levels of inputs of agrochemicals. It requires also extensive areas of cleared land for efficiency, and in this respect comes in substantial conflict environmental issues of loss of biodiversity and soil and water pollution. There is, however, no effective framework for addressing this.

Section 22 of the Land Act, as another example, clearly prohibits the cutting of trees within 50 feet of the high water mark, yet this is the area where the collection of medicinal plant resources, firewood and wood for light construction purposes are frequently taking place. Beach mining for the collection of sand as construction material is strictly regulated in the Act and is completely under the supervision of the Ministry of Lands, but still there are many breaches of the law. A similar situation occurs for the illegal cutting of mangrove along the coastline, increasing the risk of coastal erosion. In this case also there is no planning framework to address this conflict.

4. PROBLEMS AND ISSUES OF CONCERN

The Kingdom of Tonga is currently passing through a critical transition period from a traditional, mainly subsistence society towards a modern cash-oriented economy. This transition brings a number of social, technical and economic changes.

A first critical issue is that there is very limited data available to enable objective decision-making when looking at these changes and how best to manage them.

Against a background typical of a small island developing state, where natural phenomena have an important impact on day-to day life, Tonga is, like many other countries in the world, facing a rural migration to urban areas, to the capital Nuku'alofa in particular. While Tonga's population is growing at an average 0.5% annually, urban growth is 2.5%. Urban expansion takes place at the expense of encroachments of agricultural and forest land, and even of environmentally protected areas (mangrove, coastal forest). This migration process has multiple impacts. In terms of agricultural production, former producers (farmers) are becoming net consumers, thus less food is produced locally for an increased group of consumers. This agricultural production problem can be addressed by increased food imports or increased food production in the country. In the latter case more efficient and more intensive use of the land will be required.

Another significant change in moving towards a cash oriented economy is the perception of land, its access and use. Land changes from being seen as a free gift, an allotment (without direct market value), to an economic commodity, from which an income in money or goods can be earned. This is evidenced clearly in the growing interest and competition for land within and between different sectors: urbanisation, agriculture, leisure, forestry, environment, etc. and the need for it to be administered and dealt with in appropriate ways.

City expansion demands more construction material (wood, sand, cement, etc.) and infrastructure facilities including waste and sewage disposal and energy supplies. These demands can conflict with environmental safeguards, for example in relation to beach mining for sand and gravel, water supply and waste treatment, and various forms of soil and water pollution.

Resolving these conflicting demands requires an appropriate system by which they can be addressed in a balanced and transparant manner for avoiding different forms of land degradation, and against the framework of agreed national planning and priority statements. It also requires a better informed public that has adequate information to use as the basis for formulating its own views and approaches in resolving these issues.

4.1. Data Collection

One over-riding problem in providing objective views on the status of agricultural land, its tenure and the related land use issues is the almost complete lack of data on the current situation and trends. This is common across all the issues reviewed above whether, for example, relating to the status and changes of Tax Allotments or the statistics related to leasing that should be generated by the Ministry of Lands, Survey, Natural Resources and Environment.

For a national policy to be built up a reliable data base on natural resources is needed. Experience during this mission has shown that this information is often not (made) available, and that key members of institutions are sometimes not aware of the existence of such data as there is. Older documents for example make reference to soil maps of various parts of the Kingdom, drafted in the 1970s (see chapter 3.3), but these documents could not be found in the country.

It is also difficult to exchange information between agencies. The underlying challenge is that agencies or ministries sometimes consider that sharing information reduces their authority and (political) power. Record keeping, information sharing and rights of access to information are key elements in integrated planning, and their lack is therefore considered a major burden in the development of integrated policies.

In the particular case of Tonga it should nevertheless be noted that, since the public service in the country was reduced by 1,000 people, the number of government staff is limited. This situation can have multiple effects: some of the information can be misplaced, or difficult to find by newcomers; government personnel often now have multiple roles and are in the process of adjusting to these. In addition, many of them are already on a range of committees initiated to donor funded programs, and within the long-lasting internal tradition that in the absence of the boss nobody else can take any initiative, the simple search and remittance of a document can take more than a week, if not more.

The following observations on problems although largely anecdotal, reflect the views expressed during meetings and observations from field visits.

4.2. Natural Hazards

Because of its geographical position as a low-lying group of islands in a tectonically unstable area of the world, the Kingdom of Tonga is extremely vulnerable to natural hazards. The most critical issue in a worldwide concern of climatic change is a possible **sea-level rise**. Current measurements, as notified by the UNFCCC and other reports (Mafi and Crennan, 2007), refer to a global average rise of 1-2 mm/yr since measurements started in 1993. Though the reasoning behind this theory remains valid it should, however, be recalled that the recording period is far too short for drawing already firm conclusions on this phenomenon.

Figure 5 displays the results of a simulation study based on a 1m and 3m sea-level rise for Tongatapu island. Under the 1m scenario it is mainly Nuku’alofa that would be affected. The capital would break into numerous small islands, 58 km^2 of coastal area would be inundated and 10.7 km^2 of residential area. In contrast to the relatively small area that would be affected, 63% of the population of Tongatapu (which is mainly concentrated along the coastline, Figure 5) would suffer from the event (Prescott and Folaumoetu'i, 2004). An extension of the assessment to 3m rise (a realistic figure in the case of a sunami event) indicates that mostly the north-west coast and to some extent also the northeast coast would be inundated, corresponding broadly with the extension of the Fahefa, Sopu and Nuku'alofa soils.

Though the adverse effects of a sea-level rise can not be excluded, the major natural risk for the country might in the short term be from below- and above sea-level volcanic eruptions and associated tsunamis. This is due to the low altitude of most islands and to Tonga's position at the edge of the Australian and American plates where tectonic activity (earthquakes) and volcanic eruptions, followed by **tsunamis**, are not uncommon.

Cyclones form an inherent part of Tonga's climatic history. They occur on average once a year, sometimes with important damages. According to the Natural Disaster Management Report (2002), tropical cyclone Issac in 1982 caused damage of T$ 18.7 million (US$ 10.5) in the Ha'apai and Tongatapu Group. Tropical cyclone Ofa in 1990 severely affected the Niua Topotapu Group, with an estimated cost of T$ 3.2 million. Tropical cyclone Cora in 1998 hit Tongatapu, Ha'apai and 'Eua Groups and damages cost T$ 19.6 million. Tropical cyclone Waka in 2002 severely damaged the islands of Niuafo'ou, Niua Toputapu and Vava'u; the total estimated cost for the damage was T$ 104.2 million.

Historical records indicate an increase in tropical cyclone frequency in the South West Pacific since the 1960s. This trend could, however, also be attributed to improved recording of such events using advanced technologies (geo-stationary and polar orbiting satellites) and changes to tropical cyclone definition. There also appears to be a relationship between increased cyclonic activity and El Nino events. In these situations as well, conclusions can only be speculative as longer datasets are required for making scientifically sound predictions on such cyclone activities.

Little can be done to protect against cyclones as such, but the presence of a coastal vegetation (coastal forest or mangrove) can reduce wind speed and limit the damage produced by high waves and coastal erosion.

Flooding and sea-water intrusions other than tsunamis - An important side effect of cyclones is that they are often associated with strong winds and rough seas, and a break-through of the coastal sand bar protection. At that moment sea water intrusions occur, with salt water overflowing in low-lying swampy depressions. Storm surges in the hurricane season of 1982 and 1998 caused serious inundation of land in northern Tongatapu (Kanokopulo village) and especially on the western end of Nuku'alofa (Halavave and part of Kolomotu'a villages on the lagoon side). The low-lying parts of the northern part of Tongatapu, in particular the Hihifo Peninsula, still suffers from sea-water intrusion and the loss of farmland, viz. saltwater intrusion into the local freshwater lenses.

Climatic dry spells - Though the climate of Tonga is considered tropical with a dry winter and moist summer, an analysis of the monthly rainfall over the last 13 years for the 6 climatic stations indicates that dry spells extending over one month or more are not exceptional in the country. Assuming that a crop at full development has an evaporative demand of some 3-4 mm/day (90-120mm per month) and that nearly half of that amount can be taken from the moisture stored in the root zone, a month with less than 50mm rainfall can be considered as agronomically dry (strong stress conditions for the crop and substantial effect on yield), and a month with 80mm as moderately dry (moderate stress for the crop, and little effect on yield except when the preceding or following month is also dry or moderately dry).

Table 2 displays the monthly rainfall at Tongatapu Airport, considered as representative for the island as a whole. An analyses of these data shows that :

- it is common that at least one or two months per year are dry, or at least moderately dry; not one year out of 13 has no dry spell;
- 1998 and 2003 being considered as dry years had 4 dry months and 3-4 months moderately dry; 1999 being considered as an exceptionally wet year had still 1 dry month;
- dry months occur in almost all years, even in the so-called rainy season.

Drought is thus an inherent characteristic of Tongan climate, and farming systems have to take account of this hazard. This means that in an intense cropping pattern more and more (commercial) farmers have to be aware of unexpected dry spells at any time of the year and will, therefore, start to use supplementary irrigation during part of the cropping season.

4.3. Agriculture and Crop Production

Agriculture in Tonga is under strong pressure to intensify and to modernise its farming system. Besides meeting local market demands (and reducing the import of goods that can be produced in the country itself) there is also scope for expanding exports of (mainly off-season) cash crops in niche markets. This trend is supported by the knowledge that the country holds a proper climate - only limited by hurricanes and occasional drought - and good quality soils as a basis for a sustained and high-yielding production potential.

From a macro-economic perspective, the major factors limiting agriculture in Tonga are:

- the remoteness and limited size of the production area (economy of scale), which constitutes a burden on transport costs to overseas markets, and for meeting quota for international contracts;
- the competition for land with other sectors of the economy (forestry, urban development, environmental constraints, etc.) making that production increase and meeting export quota must be obtained from increased yields rather than from an extension of acreage;
- limited size and dispersion of production units;
- the vulnerability of soils in a climate characterised by very erosive rains, requiring special measures for soil protection, and land degradation in general;
- traditional farming systems which are more focused on a guaranteed risk-free food supply (fixed cropping, subsistence food crops for local consumption) rather than on high yields and cash objectives;
- high labour costs and/or labour shortage due to migration of young people overseas or to urban areas;
- lack of crop diversity guided by the specific production potential of the land and by market demands for optimising earnings from the land.

The limitations directly related to land and land use refer in particular to: (1) the adaptation of the farming system, including the use of fertilizers and pesticides, and its environmental impact in terms of soil pollution, and land degradation in general, and (2) the selection of crops best adapted to the production potential of the land and, at the same time, meet the market demands (Land capability and land suitability evaluation).

Farming systems - The traditional farming system based on a rotation of crops over 3-4 years followed by a fallow period for the regeneration of soil nutrients and organic matter can no longer be maintained because it gives too poor yields and does not valorise sufficiently the production potential of the land. To become more efficient, agriculture in Tonga must be intensified and must introduce modern farming techniques. The current shortage of labour and high labour costs do no more allow to maintain shifting cultivation practices and urge also for the use of farm machinery for field preparation and harvesting, and for alternative resource-saving conservation methods to maintain the much needed organic material in the soil.

The introduction of modern farming techniques holds a number of adverse side effects which require special attention. Intensive cropping systems without a fallow period lead to a gradual decrease of the organic matter content in the topsoil and a depletion of available nutrients; the cultivation of single crops over large production areas increases the risks on pests and diseases, and requires the use of pesticides; tillage operations and harvesting by heavy machinery can result in subsoil compaction with negative effects on root and water penetration.

In order to avoid these negative effects tillage operations must be limited and the organic material amount in the soil must be monitored. This is achieved through alternative modern farming techniques known as conservation agriculture (FAO, 2001). This is a resource-saving crop production method that thrives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. Interventions such as mechanical soil tillage are reduced to a minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt the biological processes in the soil.

Conservation agriculture is characterised by four principles which are linked to each other, namely: (1) minimal mechanical soil disturbance, (2) permanent soil cover, especially by crop residues and cover crops, (3) direct planting of crop seeds, and (4) diversified crop rotations in the case of annual crops or plant associations in case of perennial crops.

The benefits of conservation agriculture are threefolds and meet perfectly well the challenges of future agricultural production in Tonga. Economic benefits include: time saving and reduction in labour requirements; reduction of costs for fuel, machinery operations and maintenance, and overall higher efficiency, i.e. more output for a lower input. Agronomic benefits refer to an improvement of soil productivity through the increase or at least maintenance of the organic matter content in the topsoil; better structure and aeration of the soil profile; deeper rooting zones associated with a more important exploration of soil volume for water and nutrient uptake. Finally, from the environmental side this form of agriculture also reduces surface runoff and soil erosion, and increases biodiversity and carbon sequestration.

Mineral fertilizers - The application of mineral fertilizers (generally under the form of a complete NPK dressing) is needed to compensate for the plant nutrients that are exported from the soil, either at harvest or through soil leaching. Applying mineral fertilizers does no harm to the soil, the crop or the environment, provided the amounts applied are compatible with the nutrient uptake by the crop. There are, however, indications from soil leachates that there is sometimes over-fertilization in Tonga, in particular in commercial squash cultivating farms. Here also, the phenomenon needs to be properly documented before any legitimate action can be taken.

In order to avoid chemical degradation to soil and ground waters the application of fertilizers has to be adapted to the crop requirements, with a correction for additional losses through leaching, run-off and volatilisation. Table 5 provides data on the amount of nutrients exported from the soil at harvest, and gives guidelines on the rate of fertilizer compensations.

Crop	**Yield (t/ha)**	**Removal of nutrients (kg/ha)**			**Range of minimum-maximum nutrient application (kg/ha)**		
		N	**P**	**K**	**N**	**P_2O_5**	**K_20**
Banana	30	60	7	164	50-90	60-100	150-250
Cabbage	70	180	22	40	-	-	-
Carrots	80	240	35	310	-	-	-
Cassava	25	125	15	125	50-90	60-75	80-120
Citrus	15	100	10	180	100-150	60-100	100-200
Coffee	2 un-shelled	30	2	40	35-60	25-50	75-110
Maize:							
grain	4	115	30	35	60-100	50-100	30-60
stover	5.8	60	7	140	-	-	-
Pineapple		110	15	225	-	-	-
Potato:							
tuber	25	140	30	230	50-100	50-100	75-150
vines	15	100	8	220	-	-	-
Sw. potato							
tuber	15	75	15	140	-	-	-
vines		85	15	120	-	-	-
Squash	30	110	20	120	-	-	-
Tomato							
fruit	75	110	10	200	-	-	-
vines		90	12	115	-	-	-

Table 5: Nutrient removal by various crops and rang of minimum-maximum nutrient applications in kg/ha (Agricultural Compendium, 1989; Widdowson, 1993).

Organic matter (OM) is a very important soil component because of its impact on both soil physical properties (soil structure, aeration and soil-water retention) and soil chemical properties (source of nutrients like nitrogen, phosphorus and sulphur). Its content in the soil varies from less than 1% in the subsoil and in the topsoil if very exhausted (mined) soils, to more than 4-5% in the top soils under forest or at the end of the fallow period. Organic material is gradually broken down by microbial activity and by root uptake of individual components.

While in traditional farming systems the organic matter status of the soil is gradually built up in the bush fallow, in modern farming it has to be maintained through the introduction in the rotation of a green manure, e.g. a high humus producing crop. This is by preference a legume which at the same time can capture nitrogen from the air. The recently tested *Mucuna bean* seems to give interesting results in this respect, and appears to be preferred over *Pueraria* and other leguminous cover crops because its root system can better be controlled.

The maintenance of the organic matter status is one of the main components of modern conservation agriculture as described above.

Pesticides - Pesticides and other phyto-pharmaceutical products (like herbicides, fungicides, ...) are an inevitable component of modern agriculture where for economic reasons the traditional crop rotations have been abandoned, and pests and diseases develop more easily. The variety and number of pesticides is wide and their list is steadily extending. Many of them are, however, toxic to the environment and some even enter the food chain. Subsequently, the most phyto-toxic products are either banned and are replaced by less toxic and/or biodegradable variants. Though international trade and transport of the most phyto-toxic of those are officially forbidden, traces of them are still found in laboratory tests of soil and water samples.

In modern conservation agriculture pesticides are only used in the initial phases and can gradually be reduced (FAO, 2001).

To date, the World Bank (WB) and most UN Agencies are imposing the WHO (World Health Organisation) norms as a prerequisite for funding agricultural projects. Table 6 gives a selection of commonly used phyto-sanitary products in agriculture and their relative eco-toxicity level. This classification holds 4 main groups:

- class Ia: extremely toxic products, the use of which should by all means be avoided and banned by law.
- class Ib: highly toxic products which should be avoided and/or banned by law;
- class II: moderately hazardous products, the use of which should be discouraged and, if possible, be replaced by less toxic products;
- class III: slightly hazardous, to be used with moderation and following the directions.

Name of product	Environmental status and eco-toxicity level
Herbicides:	
2.4D-amine	Selective systemic herbicide. When used as recommended not toxic for most animal species, moderately toxic for fish. Half-life in soils 7-35 days depending on pH. Almost not accumulating in soils. Toxicity class WHO: II.
MSMA	Selective contact herbicide with some systemic properties. Half-life in soil 55 days. Toxicity class WHO: II
Daconil	Selective contact herbicide. Very soluble in water. Used in combination with atrazine for total weed control. Toxic to bees. Toxicity class WHO: III. Toxic when swallowed.
Diuron	Selective systemic herbicide. Non-toxic for birds, moderately toxic for fish. Rather persistent in soils (half life 94 days); phyto-toxic residues in soils disappear within 4-8 months. WHO: not classified.
Folar	Herbicide phyto-toxic to many annual plants and to aquatic life. Half-life in biologically active soil: 30-60 days. Toxicity class

	WHO: III. Moderately harmful when swallowed.
Gesapax (Ametrine)	Selective systemic herbicide. Half life in soil 55 days. Loss from soil is mainly from biological degradation. Toxicity class WHO: III. Harmful if swallowed.
Gramoxone	Non-selective contact herbicide, absorbed by the foliage. Strong absorption by soil. Toxicity class WHO: II. Toxic when in contact with skin and if swallowed. Irritant to eyes, respiratory system and skin.
Glyphosate/Round Up	Non-selective systemic herbicide, absorbed by foliage, inactivated on contact with soil. Low mobility in soil. Non- toxic for birds, fish, insects. Half-life in soil 28-70 days. Toxicity class WHO: III. Irritant, serious damage to eyes.
Insecticides:	
Monochrotophos	Systemic insecticide-acaricide with contact and stomach action. Controls a broad spectrum of insects. Not phyto-toxic when used as directed. Rapidly degraded (half-life in soil 1-5 days). Medium to low mobility in soil. Toxicity class WHO: Ib. Toxic in contact with skin. Very toxic if swallowed. To be avoided.
Disulfoton/Disyston	Organo-phosphate systemic insecticide-acaricide absorbed by roots. Not phyto-toxic when used as directed. Very rapidly degraded and medium to low mobility in soil. Toxicity class WHO: Ia. Should be avoided.
Terbufos	Organo-phosphatic soil insecticide and nematicide with stomach action. Has an effective initial and residual activity against soil dwelling arthropods. Rapid degradation in animals, plant and soil. No accumulation in soil (half-life 9- 27 days). Toxicity class WHO: Ia. Very toxic in contact with skin and if swallowed. Should be avoided.
Decis	Pyrethroid. Non-systemic insecticide with contact and stomach action. Fast acting and effective against a wide range of pests. Very toxic to fish. Strong absorption to soil; microbial degradation in 1-2 weeks (half-life 30 days). No incidence on microflora and nitrogen cycle. Toxicity class WHO: II. Harmful in contact with skin and if swallowed.
Systoate/Dimethoat	Organo-phosphatic systemic insecticide-acaricide with contact and stomach action. Affects a wide range of insects. Not phyto-toxic when used as directed. Moderate toxicity for birds, fish and aquatics. Is rapidly absorbed by the silt fraction in the soil. Rapidly degradable (half-life 2-4 days). Toxicity class WHO: II. Harmful in contact with skin and if swallowed.
Evisect	Selective insecticide with contact and stomach action. Not phyto-toxic to most plants at recommended dose. Toxic for birds and fish. Rapid degradation in soil and plants. Half-life in soil 1-4 days. Moderately mobile in soil. Toxicity class WHO: II. Harmful in contact with skin and if swallowed.
Cartap/Pardan	Systemic insecticide with stomach and contact action. Insects discontinue feeding and die from starvation. No accumulation in soils (half-life 3 days). Toxicity class WHO: II. Harmful in contact with skin and if swallowed.

Unden/Propoxur	Carbamate. Non systemic insecticide with contact and stomach action. Controls sucking and chewing insects, as well as migratory locusts and grasshoppers. Relatively mobile in soil, but degrades rapidly. Toxic for aquatics and bees. Accumulates in soil (half life 39-155 days). Is phyto-toxic for some flowers at high doses. Toxicity class WHO: II. Toxic if swallowed.
Karate	Pyrethroid. Non-systemic insecticide with contact and stomach action and repellent properties. Affects large spectrum of insects. Almost non-toxic for birds, toxic for aquatics. Moderately degradable to persistent in soil (half-life 4-12 weeks). Almost immobile in soils, and accumulation in topsoil. Toxicity class WHO: II.
Furadan	Carbamate. Systemic insecticide-nematicide with predominant stomach and contact action. Used for control of soil dwelling and foliar-feeding insects and nematods. Half-life in soil: 30-60 days. Toxicity class WHO: Ib. Very toxic very inhalation and if swallowed.
Aldicarbe	Insecticide-nematicide. Toxicity class WHO: Ia. To be avoided.
Fungicides:	
Cryptonol	Fungicide-bactericide. Is a common disinfectant in horticulture. Non-toxic. Toxicity class WHO: III. Harmful if swallowed.

Table 6: Name and environmental status of a number of currently used phyto-pharmaceutical products used in modern agriculture
(Roberts and Kearny, 1995; Tomlin, 1997).

Mechanical farming - To date farm labour is scarce and expensive, and therefore, modern agriculture in Tonga has to shift to mechanisation for field preparation and harvesting. Farming operations are facilitated by the grouping of small plots into larger fields and the elimination inside the plots of all forms of obstacles like trees and bush remnants. The felling of trees - e.g. individual or groups of coconut or mango trees - reduces biodiversity and creates loss of habitat.

The frequent use of heavy machinery leads however to a compaction of the subsoils, especially if operations are carried out in very wet soils, and hampers the easy penetration of the larger roots, while at the same time it might create temporary water-logging at the contact of the plough layer with the subsoil. These features can easily be observed in the field and even directly measured by field infiltration tests and the use of penetrometers. Although such conditions are frequently mentioned in environmental studies effective measurements are scarce, if ever done. A better documentation of the phenomenon is needed before their real impact can be estimated.

By shifting towards conservation agriculture the negative effects of this soil compaction can gradually be lowered, especially if the number of machine passings over the field is combined with the incorporation of more organic material in the soil.

4.4. Land Capability and Suitability

A basic principle in modern sustainable agriculture is that the land be used according to its best potential. An important tool in achieving a performing agriculture is thus to make correct choices in the crops which, at the same time, are best adapted to the properties of the land and meet the market opportunities. For these choices to be made properly it is necessary to know the land use potential and appropriate management techniques to explore it (land capability), and to assess the anticipated performances of individual crops (land suitability).

Land capability deals with the production potential of the land and the management aspects related to this potential in general terms, without consideration given to the specific requirements of each individual crop : subsistence food crops, vegetable cash crops, tree cash crops, pasture, forestry, leisure, residential and urban uses, etc. so that reasonable options can be taken for development and/or investment. Land suitability evaluation goes one step further and deals with the assessment for individual crops (cassava, pumpkins-squash, pawpaw trees,..), each of them with their own specific growth and production requirements. Both land capability and land suitability reflect thus different levels of detail in the assessment of the land use potential, and thus in terms of land use planning.

The technical details and guidelines on the overall land capability and land suitability evaluations for a number of selected crops in Tonga are outlined in the technical annex to this report. The results of this exercise applied for the island of Tongatapu are summarized below.

Land capability - Overall, the land use potential of Tongatapu is quite high, though some natural hazards require adequate management. The land capability of Tongan soils is mainly determined by climatic and soil conditions. The irregularity of the precipitation, with very high rainfall periods alternated with dry spells, may locally create conditions of temporary water logging and drought with an adverse effect on yields. The occurrence of hurricanes may damage tree crops.

The soils of Tonga have a high natural fertility and offer an excellent medium for crop production. Because of their high clay content they are, however, difficult to work in some parts of the year. The best soils for root, vegetable and tree crops are the Fahefa, Vaini and, to a lesser extent, the Lapaha soils for vegetable crops. Sopu soils are generally unsuitable for crop production, while the Nuku'alofa and Fatai soils require special measures of irrigation and drainage, respectively.

The capability assessment for the three major land utilization types: root crops, vegetable crops, and tree crops are summarized in Table 7 below.

Soil type	Capability level and constraints
1. Capability for root crops : early and sweet yams, giant taro, American taro, Irish potato, sweet potato, kava	
Fahefa and Vaini soils (flat phase)	High production potential. Slight moisture deficit during dry spells. Slight rooting limitations in clayey subsoils. Growth of Irish potatoes restricted to cool season.
Lapaha soil (flat phase)	Slow subsoil permeability and reduced aeration. Temporary water logging. Sweet potatoes and early yam cultivation needs mounding.

Fahefa, Vaini and Lapaha soils (rolling phase)	Almost equal capability as flat phases, but soil conservation measures (contour cultivation, strip cropping, mulching) are required to avoid surface erosion.
Fatai soil	Imperfect drainage and flooding risks. Temporary water logging promote root rot and reduce production.
Nuu'alofa soils	Unsuitable due to excessive drainage, seasonal moisture deficiency and nutrient imbalance.
Sopu soil	Unsuitable due to flooding risk and sea water intrusion.
2. Capability for vegetable crops : cabbage, carrots, beans, cucumber, eggplant, onion, pupkin-squash, tomato, water melon	
Fahefa and Vaini soils (flat phase)	High capability. Heavy texture and firm subsoils require deep tillage and mulching. Risk for subsoil compaction under mechanised cultivation. Under intensive cropping need for adequate fertilisation.
Lapaha soils	Less versatile than Fahefa/Vaini. Slow subsoil permeability and reduced aeration require subsoiling. Workability.
Fahefa, Vaini, Lapaha rolling phase	Less versatile than flat phase, because additional conservation measures required to avoid topsoil erosion.
Fatai soils	Only moderately suited for vegetable crops due to imperfect drainage and local flooding.
Nuku'alofa soil	Unsuitable because of drought, salt spray and nutrient imbalance.
Sopu soil	Unsuitable due to poor drainage and seawater intrusion.
3. Capability for tree crops: banana, breadfruit, coconut, mango, orange, pandanus, paper mulberry, coffee, vanilla	
Fahefa and Vaini soils	Very suitable. Adequate fertilisation required under intensive cultivation.
Lapaha soil	Suitable with slight limitation due to firm, compact subsoils and poor aeration.
Fahefa, Vaini, Lapaha rolling phase	Require conservation measures: mulching, inter-row grass strips, across slope planting.
Fatai	Temporary water logging restricts choice of trees. Inter-row drainage recommended.
Nuku'alofa soil	Affected by drought and salt spray. Limited choice of trees.
Sopu soil	Unsuitable because of poor drainage, flooding and salt intrusion.

Table 7: Land capability classification for three land utilisation types: root crops, vegetable crops and tree crops in Tongatapu (adapted from Trangmar, 1993).

Land suitability - Land suitability deals with the fitness of the land for a defined use, e.g. a specific crop cultivated under a well-defined management system. A land suitability classification is a ranking of soils (or land units) based on the matching of crop growth and production requirements against major land properties. Because plant growth is mainly determined by climatic, soil and terrain factors, the criteria involved in this matching exercise rely to all three groups of these factors. Obviously, as different crops have different growth and production requirements, separate criteria have to be defined for each specific crop.

The procedures referring to the definition of growth criteria and their matching with land properties of Tongan soils are explained in full detail in Technical Annex A to this report. The conclusions of this exercise are summarized in the Tables 8, 9 and 10 below.

Soil type*	**Crop**							**Constraints and Comments**
	Giant taro	**Taro**	**Irish pota**	**Swe potat**	**Earl yam**	**Swe yam**	**Kava**	
No special management required:								
Fahefa	S1	S1	S1	S1	S2	S1	S1	Nutrients, moisture
Vaini	S1	S1	S1	S2	S2	S1	S1	Nutrients, texture
Lapaha	S2	S2	S2	S3	S3	S2	S3	Subsoil permeability
Fatai	S2	S2	SS	N	S3	S3	S3	Drainage
Usually practicable without special management								
Vaini low	S2	S2	S3	S3	S3	S3	S3	Nutrients, wetness
Lapaha low	S2	S2	S3	S3	S3	S3	S3	Subsoil perm., wetn
Nuku'(Lsa)	S3	S3	N	N	S3	S3	N	Drought, alkalinity
Production only with special measures (mulching, erosiun control, ...								
Fahefa rol	S2	S2	S3	S3	S3	S3	S2	Nutr., moist., slope
Vaini rol	S2	S2	S3	S3	S3	S3	S2	Nutr., text., slope
Lapaha rol	S2	S2	S3	S3	S3	S3	S3	Subsoil perm., slope
Nuku'(Sa)	N	N	N	N	N	N	N	Drought, salt, alkal.
Sopu	N	N	N	N	N	N	N	Drainage, flood, salt

* Vaini low, Lapaha low: low-lying phase of Vaini and Lapaha series; Nuku'(Sa) and Nuku' (Lsa) : Sandy and loamy sand phases of Nuku'alofa series; Fahefa rol, Vaini rol and Lapaha rol: sloping phase of Fahefa, Vaini and Lapaha series.

Table 8 : Suitability evaluation for selected root crops in Tongatapu
(adapted from Trangmar, 1993).

Soil type*	**Crop**							**Constraints and Comments**
	Cabb age	**Carr ot**	**Bean s**	**Cucu mber**	**Egg plant**	**Squ ash**	**Wat melo**	
No special management required:								
Fahefa	S1	S1	S1	S1	S1	S1	S1	Nutrients, moisture
Vaini	S1	S2	S1/2	S1/2	S1/2	S2	S2	Nutrients, texture
Lapaha	S2	S3	S2	S1	S2	S3	S3	Subsoil permeability
Fatai	S3	S3	S3	S2	S3	S3	S3	Drainage
Usually practicable without special management								
Vaini low	S3	S3	S3	S2	S3	S3	S3	Nutrients, wetness
Lapaha low	S3	S3	S3	S2	S3	S3	S3	Subsoil perm., wetn
Nuku'(Lsa)	N	S3	N	S3	S3	N	S3	Drought, alkalinity
Production only with special measures (mulching, erosion control, ...								
Fahefa rol	S3	S2	S2	S2	S2	S2	S3	Nutr., moist., slope
Vaini rol	S3	S2	S2	S2	S2	S2	N	Nutr., text., slope

Lapaha rol	S3	S3	S2	S2	S2	S3	N	Subsoil perm., slope
Nuku'(Sa)	N	N	N	N	S3	N	N	Drought, salt, alkal.
Sopu	N	N	N	N	S3/N	N	N	Drainage, flood, salt

* Vaini low, Lapaha low: low-lying phase of Vaini and Lapaha series; Nuku'(Sa) and Nuku' (Lsa) : Sandy and loamy sand phases of Nuku'alofa series; Fahefa rol, Vaini rol and Lapaha rol: sloping phase of Fahefa, Vaini and Lapaha series.

Table 9: Suitability evaluation for selected vegetable crops in Tongatapu (adapted from Trangmar, 1993).

Soil type*	**Crop**							**Constraints and Comments**
	Banana	**Bread fruit**	**Coco nut**	**Coffe**	**Mang**	**Pape Mulb**	**Vanill**	
No special management required:								
Fahefa	S1	S1	S1	S1	S1	S1	S1	Nutrients, moisture
Vaini	S1	S2	S1	S1/2	S2	S1/2	S1/2	Nutrients, texture
Lapaha	S2	S3	S2	S2	S3	S2	S2	Subsoil permeability
Fatai	S3	S3	S3	S3	S3	S3	S3	Drainage
Usually practicable without special management								
Vaini low	S3	S3	S3	S3	S3	S3	S3	Nutrients, wetness
Lapaha low	S3	S3	S3	S3	S3	S3	S3	Subsoil perm., wetn
Nuku'(Lsa)	N	N	S2	N	S3	S3	N	Drought, alkalinity
Production only with special measures (mulching, erosiun control, ...								
Fahefa rol	S1	S2	S1	S2	S2	S3	S2	Nutr., moist., slope
Vaini rol	S2	S2	S2	S2	S2	S2/3	S2	Nutr., text., slope
Lapaha rol	S2	S3	S2	S3	S3	S3	S3	Subsoil perm., slope
Nuku'(Sa)	N	N	S3	N	N	N	N	Drought, salt, alkal.
Sopu	N	N	N	N	N	N	N	Drainage, flood, salt

* Vaini low, Lapaha low: low-lying phase of Vaini and Lapaha series; Nuku'(Sa) and Nuku' (Lsa) : Sandy and loamy sand phases of Nuku'alofa series; Fahefa rol, Vaini rol and Lapaha rol: sloping phase of Fahefa, Vaini and Lapaha series.

Table 10: Suitability evaluation for selected fruit tree crops in Tongatapu (adapted from Trangmar, 1993).

The suitability evaluation for crops in Tonga shows that there is scope for a wide diversification of crop production, both for export and for meeting the local markets. This refers in the first place to tropical fruits, for which Tonga has a high potential. Papaya (paw-paw), eggplants and mango are already locally grown, but their production can substantially be increased and improved. Other fruit trees like ramboutan, lychee, soursop, etc. have good potential for export as well, both as fresh fruits or processed. In the first case the producers will have to cope with the very strict quality regulations imposed by importing countries (fruit fly in particular), and this will need the structural support of the Ministry of Agriculture. A reasonable alternative would be to process the fresh products into juices.

Additional cash crops to be taken into consideration are : (Robusta) coffee, vanilla and cacao. A small plantation of Robusta coffee is already in place in Tongatapu, but it is believed that a good potential for these products exists also on other islands. The advantage of these commodities is that they can be harvested and shipped as dry products. A similar situation occurs for the production of **vanilla** which is traditionally grown in the Kingdom and for which the pollination technology is known.

4.5. Land Degradation

Land degradation is the process whereby the quality of land (soil) properties deteriorates and the overall production potential decreases. This process affects the natural equilibrium in the soil, disturbs biological life and exchange processes, and reduces the output of the land. Land degradation can be reversible, as for example in the case of nutrient depletion, but can also be irreversible and fatal, as is the case of severe erosion with a more or less complete soil loss. It can be the result of natural hazards or be enhanced by human action.

The degradation phenomena related to natural hazards have been discussed at large in chapter 4.2. of this report. These involve flooding or overflow as a result of heavy rainfall, forest damage due to cyclones, coastal erosion, etc. Little can be done to avoid these events and, therefore, the focus in these cases is more on conservation and protection so as to reduce the damage. Coastal erosion for example can be seriously reduced by maintaining a protective mangrove vegetation, avoiding beach mining or conserving a coastal forest vegetation.

Most of the land degradation encountered in Tonga is, however, created by human action and is in particular due to the mismanagement of land in vulnerable areas. This refers in particular to soil erosion (physical land degradation) as a result of deforestation, and to soil pollution (chemical) and compaction (physical) as side effects of modern agricultural techniques.

The soils of Tonga are vulnerable to erosion because they are usually made up of a superposition of two (volcanic ash) layers with different texture and water-retention properties. As long as these soils are covered by a protective forest vegetation they are relatively stable. This changes however from the moment this cover disappears and the surface is hit by the kinetic energy of intensive tropical rains and the profile gets saturated with rainwater. This vulnerability is further increased because, as a result of mechanised farming, the subsoils become rapidly compacted, hampering thus further water infiltration. The key solution to this problem is either to keep the most vulnerable soils under a form of forest (either complete forest, or agroforestry), or to shift towards conservation agriculture, whereby tilling operations are reduced and the organic material status in the profile is well maintained.

The principles of conservation farming have been explained above (chapter 5.3). Full details on this alternative system of modern farming can be obtained from http://www.fao.org/ag/agca or from FAO (2001).

The challenge of maintaining an important forest cover, in particular in Tongatapu where most of the native forests have already been cut, is not only important for soil protection but also for other ecological reasons, in particular for the conservation of terrestrial biodiversity.

A tropical forest is a unique closed ecological system. Though leaf fall and decaying stems a considerable quantity of organic litter falls on the surface, and provides food for an intensive biological activity and plant growth. The deep rooting trees ensure a constant pumping and circulation of plant nutrients released by the mineralisation of organic debris and from the weathering of the deeper soil layers. The thick canopy protects the soil surface from the direct exposure to sun light and intensive rain. In this close system there is little nutrient loss.

Once a forest is cleared its original biological cycle is markedly changed. The vegetation with its production of organic debris is removed and/or burnt, while the root system disintegrates. There are no longer any deep roots to recycle nutrients back to the surface, nor to bring up fresh nutrients from lower strata. The supply of organic debris to the surface is also greatly reduced. The direct exposure of the surface to the sun increases the rate of mineralisation of organic material and this impairs water infiltration and water retention capacities in the soil. Under these conditions a new equilibrium is installed, and when submitted to long-time cropping the nutrients exported by the crop at harvest have to be replenished by the application of fertilizers and one form or another of supply of organic material.

The second major environmental challenge is the role played by the agrochemicals in modern agricultural production systems, and their possible effect in soil and water pollution. Both forms of land degradation are often associated with large-scale commercial agriculture, but this is not necessarily the case. It can anyhow be avoided by adapting the applied amounts of fertilizers to the crop requirements (Table 5) and to use only pesticides which are biodegradable or that can easily be broken down in non-toxic elements (see above,Table 6).

Soil fertilization is needed to sustain economic yields. Intensive cropping without due application of fertilizers leads to a gradual depletion (mining) of soil nutrients. Applying too much fertilizers is, however, costly and non-economical because nutrients which can not be retained by the soil particles (clay and organic material) in the topsoil are either leached (nitrogen, potassium) or lost with surface run-off. Hence, it is important to maintain the stock of soil organic material as this favourably influences the nutrient-retention capacity of the soil.

Chemical pollution of soils and ground waters can derive from various sources : pesticides and fertilizers, salt spray and seawater intrusions, oil spills and fuel, or industrial chemicals transported in soluble form with the rainwater to the deeper layers of the soil and ground waters. Accumulated biological pollution can originate from septic tanks, pit latrines and pigs. Though *in se* the soil has a good buffering capacity and is able to break down most of non-soil components, the pollution can reach a critical point so that an aquifer has to be abandoned, as was the case of the former Nuku'alofa township aquifer.

The Ministry of Agriculture, Food, Forests and Fisheries (MAFFF) is responsible for promoting agricultural production and supervising use of fertilizers and irrigation. They have no facilities for monitoring contamination of groundwater by pesticides or fertilizers, or hold no records on who is pumping irrigation water.

The use of pesticides and fertilizers is a main concern in relation to the impact of agriculture on the environment. Squash production has resulted in a substantial increase in imported agrochemicals: T$ 700,000 was spent on pesticides in 1999-2001 and T$ 1 million on fertilizers in the same period. Application of fertilizers has grown from 5 kg/ha at the end of the 1980s to 80 kg/ha at the end of the 1990s. There is anecdotal evidence that eutrophication of the lagoon at points where groundwater is seeping through may be caused by fertilizers. It is also likely that effluent from septic tanks is an additional contributing factor. Traces of pesticides such as lindane, DDT, aldrin and heptachlor (now banned) were found in well water in 1984, and traces of organo-chlorines were found in sediment and shellfish of the central Fanga'uta lagoon in 2002 (Mafi and Crennan, 2007).

It is also assumed that coral die-off might be attributed to a combination of nutrient run-off from urban and agricultural sources. Concentrations of nitrates draining from the rootzone of squash were measured to be approximately 5 times the WHO limit for drinking water quality. Traces of dieldrin, diazinon and carbyl were also found (Mafi and Crennan, 2007).

The problem of soil and water pollution in Tonga is that it is based on too little and often isolated or old data. The two initial studies to which the soil and water pollution claims in Tonga again and again refer, can not be traced. Also, the very much needed follow-up studies for monitoring and effective reclamation of the problem are not done, and nobody seems to worry about.

4.6. Land Tenure and Land Administration

The Land Act (1988) is the basic law that defines the forms of access to land and guides the system of registered allocations of Town and Tax Allotments and their corresponding hereditary rights. Decisions about allocations and the process of allocating land are all based on these notions. It defines also the nature and form of leases to third parties. The Land Act overrides all other legislation on land.

The Land Act has often been pointed to as a constraint on development, but this is not entirely correct because the Act contains a number of sections, for example in terms of use regulations, which might promote rather than hamper development. A part of the problem is that the Act has no proper by-laws and regulations to implement and enforce its legislation. The absence of such regulations is sometimes used by those who want to maintain traditional rights and customs, particularly in relation to land use questions. In some countries such circumstances may also be an opportunity for administrations to benefit from the lack of clarity in the law and of transparency in their operations, to the detriment of users of land administration services.

The Land Act's provisions should be updated as an interim strategy to address key issues. For example, the obligation under the Tax Allotment provisions to plant coconut trees (Section 74) could be repealed, because it is no longer considered relevant. The provisions could be maintained for the allottee to be obliged to use the land, either by himself or through a lease contract, but under more modern lease terms and conditions. In such a revised lease system the allottee should have the covenant from the lessee that the land will be used in a sustainable way, and that the necessary conservation methods will be carried out to avoid any degradation of the soil.

In the longer term, the review of the Land Act may indicate that more fundamental adjustments are required to land leasing in Tonga and its related tenurial framework. This is likely to be a longer term question and will require more substantial data for effective policy considerations and consultation.

4.7. Planning, Land Use and Conflict Resolution

The Kingdom of Tonga has no established system of spatial planning. No agency in Tonga is charged with preparing plans. The primary planning work undertaken by the Central Planning Department (CPD) and its associated agencies was primarily economic. Some of the work carried out by the Department of Environment (DOE), now being part of the Ministry of Lands, Surveys, Natural Resources and Environment (MLSNRE) in terms of global resource management planning for Tonga, goes some way towards a basis for broad-based spatial planning. However, this activity is not currently enshrined in any active legislation. It is included in the Natural Resources Planning Bill which was drafted in 2002, approved by the Cabinet and Privy Council in 2005, but was never passed by Parliament.

The Tonga Integrated Urban Development Project: Urban Planning Management System (TIUDP, 2006) is another attempt to enact urban development, but is still under discussion. The Environmental Impact Assessment Act (EIA), passed in September 2003, provides a framework for development planning which aims to prevent the making of arbitrary land use decisions, but is not operational.

With no forward planning and no plans, there are no spatial guidelines to assist decision making on either strategic or local development issues. There is also no structured identification of development or land use issues that may arise. Land development is primarily led by the land tenure system, and by the Land Act (1988) which is the direct emanation of it.

Another important issue is that the Kingdom of Tonga has no tradition and no experience in *integrated* planning. Many line ministries have developed their own acts and regulations, but only on a strict sector basis. A good example of this attitude were the reactions recently voiced at the presentation of the new (draft) Forest Act. A number of sectors of the economy other than forestry believed that this Act would give too much power to the Forestry Division in the Ministry though the basic goal of the exercise was to stop further forest encroachment, and to give forest management the place it deserves in the economy (timber exploitation) and as a means to protect the environment (preservation of biodiversity).

Effective planning and management of land are, worldwide, recognised as necessary tools to facilitate ordered and sustainable development. Problems associated with unplanned and uncontrolled development are already being experienced. The still on-going cutting of the mangrove vegetation for residential expansion along the shoreline of the central lagoon is prohibited by law, but still takes place. Unauthorized beach mining and quarrying are still happening. Water quality treatment, sewage, and related problems, with implications for many other sectors are a major challenge in Tonga. In commercial farming isolated trees or bush fallow are destroyed despite its being forbidden. Conflicts are on the rise between environmentalists, foresters, agronomists and urban planners about unauthorised forms of land use. Issues associated with urban growth, rural migration and inappropriate settlements are often compounded by traditional land ownership customs, and conservative attitudes to change.

In a logical proposed national planning legislation for the country, two levels of planning should be foreseen:

- an overall strategic and integrated spatial planning which focuses on the land use potential and efficient sustainable use of land in general without deteriorating the land qualities for the future; this should be a long-term planning and a basis for the country's national land use policy;
- a specific sector-related planning, including agricultural, forestry, urban and other plans which should provide the base for the short- and mid-term priorities in the overall land use policy.

At both levels the focus should be on highlighting the directions for growth, and in identifying key deficiencies both in economic and environmental terms. The direct objectives of planning are to provide clear guidance where investments should be made, or not made, and where land degradation can be avoided. These objectives are generally not in contradiction with the concepts outlined in the Land Act (1988).

4.8. Public Awareness

There is a growing awareness amongst school children and secondary school students about the risks of degradation of natural resources. Because of the high rate of school attendance in the country, awareness creation through the student population is a very effective tool. Awareness creation on environmental issues is further conducted through public meetings, school presentations, TV programs, theatre and radio broadcasts. However, litter is found in the public domain, and many illegal activities like the cutting of mangrove forest for fuel wood of sand collection on protected beaches are still taking place. There is a need to reconnect with traditional values regarding protection of resources.

As is the case in many other countries few NGOs deal with environmental issues, such as Tonga Development Trust. This is a local NGO with strong involvement in tree planting, keeping the community clean, and general rural development activities.

Awareness creation in other domains of the environment happens also indirectly. The National Agricultural Research Farm in Vaini organises training courses for farmers four times a year, focusing not only on agronomic aspects (growth and production of crops like squash, vegetables, yams, etc.), but also on the safe use of pesticides and fertilizers. No courses on special environmental issues are organised, but environmental aspects and sustainable crop and farm methods are currently included in the training programs. The training staff agrees that there is a need to extend the courses with a land degradation component.

At farmers' level awareness has still to be increased on the safe use of pesticides, and the advantages of organic farming. A model farm could be established to demonstrate irrigation techniques, rain water collection and groundwater management, application of organic and integrated pest control, the appropriate use of fertilizers (including the treatment of pig manure and compost), and ecological sanitation including management of livestock.

A major problem which is constantly coming up in most integrated projects, and which is also expected to happen in Tonga, is the future collaboration between the different line ministries when dealing with an integrated approach to land use planning. Traditionally, each line ministry considers his type of land use as a priority, and this leads automatically to conflicts which can only be overcome by decisions taken by an overruling body, generally an interministerial commission or agency directly under the Prime Minister. In this respect, it has been a wise initiative to allocate already many powers to the Ministry of Lands, Surveys, Natural Resources and Environment.

5. Land Use Planning in Tonga

5.1. Rationale for an Integrated National Land Use Policy

The Kingdom of Tonga is faced with an important migration trend resulting in a rapid development of the urban population, Nuku'alofa in particular. This means that the number of food producers decreases while the net consumers increase. At the same time the country's foreign trade report shows a dramatic imbalance, with consumer goods exceeding overall exports by a factor of almost 20 in 2007. This alarming trend must urgently be stopped, and this can only be achieved by improving land use efficiency and increasing agricultural production, both to supply local markets (and avoid food import) and to increase exports.

Given the relative scarcity of land in Tonga the objectives outlined above will automatically lead to a competition for land. This situation has to be kept under control through an integrated land use policy which has overriding power over sector policies, and which should define the use options of land, viz. agricultural against other uses, keeping in mind the long-term development strategy of the country. If needed, also the traditional land tenure regulations should be adjusted to the present situation.

To increase agricultural outputs the former traditional slash and burn farming system has to be abandoned and modern farming techniques introduced. These refer to the gradual introduction of commercial farming, but under the condition that this is not exclusively done in the way it has been achieved in the past 10 years, i.e. with full mechanisation of field operations (mainly due to the present-day shortage and cost of labour), enlargement of field size, monocropping and unlimited/uncontrolled use of agrochemicals. Depending on the opportunities on international markets, there might indeed also be scope for small-scale farming of niche products. The most beneficial crop selection will be derived from a land suitability assessment adjusted by current market demands.

The transition towards modern commercial farming holds risks for environmental degradation if no sustainable practices are applied and appropriate soil conservation methods imposed. In this respect it is recommended that the possibilities for conservation farming be explored, in particular with respect to reduced tilling operations and the introduction of cover crops in the rotation as a means for the conservation of organic matter in the soil. Both conditions will automatically result in reduced fertilizer needs and the application of less aggressive and less toxic pesticides. Given the nature and vulnerability of Tonga's soils these conservation practices need to be strictly monitored and their implementation be enacted in a new legislation, with enforcement procedures and penalties included.

5.2. Elements of a National Land Use Policy

For a national land use policy to be successful a number of requirements have to be met. These require the following steps to be taken:

1. In first instance, due reference should be made to the long-term development objectives of the country; the strategic goals of the policy should correspond and be in full support of these long-term objectives;
2. Clear choices should be made on the crops to be grown and on the technology and production methods used;
3. An enabling environment should be created to allow for optimal production methods and for a proper infrastructure for the marketing of the produce;
4. The sustainability of the production system should be guaranteed by applying appropriate soil conservation measures; while optimising agricultural outputs land degradation should be avoided.

Long-term development objectives - Tonga's long term development plan calls for an intensification of agriculture in order to:

- increase the availability of locally produced food to improve nutrition and to reduce the dependence on imported foodstuffs, and
- increase the production of quality export commodities.

To achieve these objectives, the suggested national land policy will have to focus on improving the farming systems and practices to increase the sustainable productivity of agricultural land while avoiding any form of degradation of natural resources. In order to harmonise economic objectives and environmental protection it is therefore recommended that the higher demands for agricultural outputs should primarily be met by increasing the efficiency of the present farming systems, and that the extension of crop land should only be considered as a second option. This means that only part of the Tax Allotments which are nowadays unused and left idle should be used for cropping, while another part – for example those belonging to non-resident owners – could be reforested.

Choice of crops and production methods - The traditional slash and burn farming system, including a relatively important fallow period is too inefficient and too labour-intensive, and can no longer compete with modern production systems. The traditional Tongan diet is based on starch food and root crops, and it is expected that particularly in the remote outer islands and in rural areas in general, these food habits will persist for a long time. In the choice of crops to be grown subsistence root crops such as yams, taro, cassava, potatoes and kava will therefore continue to occupy a major place in the production process.

The gradual change in diet of city dwellers in Tonga, the needs for a growing tourist industry, and the opportunities for export to foreign markets present otherwise good perspectives for the growth and marketing of fresh vegetables and tropical fruits like beans, cabbage, carrots, cucumber, onions, pumpkins and others, as well as bananas, citrus, mango, paw-paw, etc. Some high-value niche products like litchi and ramboutan might give hopeful perspectives as well. The proper development of these fresh products will however require government support in the form of a technical advice and the set-up of a research unit for crop selection and the permanent monitoring of quality control in the country.

Finally, like pumpkins-squash and taro were once niche crops for export markets in Japan and Korea, there is still scope for research on growth and development of special crops. Examples of these are: perfume oils (e.g. patchouli which is successfully grown in Indonesia), phyto-pharmaceutical products (like cloves), or spices like peppers or vanilla which is already successfully grown in some parts of the country. Many of these crops can be grown in smaller plots, avoiding the environmental risks of monoculture exploitation over larger fields and with the use of heavy doses of fertilizers. Agroforestry on the basis of fruit trees is an option as well for an environmental-friendly land use.

Because of the wide range of tropical crops that can be grown in the country there are also theoretical growth potentials for a number of industrial crops like oil palm, pineapple, coffee or rubber. Because of the extend of the plantations needed for an economical production unit, these crops are of less interest in a small country like Tonga. Moreover, such plantation crops present a problem for the maintenance of terrestral biodiversity as well.

Finally, it should be recalled that Tonga imports many poultry products, most of which could be produced inland. There exist already a few poultry farms in the country, but the high costs of the (mainly imported feed) constitutes still a problem for their economic development. Maize cultivation is, however, feasible in Tonga and, therefore, the development of this crop should be taken into consideration.

Most of the present-day grown export crops require commercial large-scale production units involving extensive uniform fields, mechanisation of field operations and the use of important amounts of fertilizers and pesticides. Unfortunately, experience has shown that these modern production methods create a number of adverse environmental hazards which have to be avoided. Too frequent tillage operations and the abandonment of the traditional fallow period leads in the long run to a reduction of organic matter and in a structural degradation of the soil, in particular to a compaction of the subsoil, formation of surface crusts and ultimately to erosion. This degradation process requires that alternatives have to be introduced under the form of conservation agriculture, involving limited tillage, the introduction of cover crops for surface protection and accumulation of organic material in the soil, and adapted crop rotation to reduce the application of fertilizers and pesticides.

For some niche products for which no export quota are required, smaller production units that can be managed by a single family might be sufficient. Also, fruit trees grown for the local market could produced in such small enterprises and in an agroforestry system.

Creation of an enabling environment - The present land tenure system in the country is based on the allocation of Tax Allotments of 3.33ha, and the prohibition of land sales. In order to cultivate larger farm units as is the case for mechanized commercial farming the farmer-entrepreneur must thus explore the lease market to obtain the necessary acreage for an economically-interesting farm unit. Though the Land Act (1988) allows for the lease of land, this form of land acquisition brings many problems for both the leaseholders and lessees.

The most frequently heard comments in this respect refer to the nutrient mining of the land by the lessee (related to not restoring the original natural fertility of the plot), the destruction of individual trees and remnants of bush fallow in the parcels so as to facilitate mechanical farming, the pollution of land and/or groundwater, the compaction of subsoils after a few years of mechanical farming, etc. The legal formalisation of the lease contract is also said to take too much time insofar that, forced by the imperatives of the crop calendar, many leases effectively start before any lease contract has been signed.

To overcome the critics described above, the Government should create enabling conditions for (1) fastening the administrative procedures for the official lease contracts; (2) install an independent commission to handle conflicts between lessee and lease holders on the quality of the land, and (3) for the critical issues which can not be observed *de visu*, as is the case for nutrient mining and subsoil compaction, make provision for soil sampling and proper interpretation of data in the case of critical soil conflicts.

There exist scientific methods to determine exactly the physical and fertility status of soils as referred to above. Though it would be recommended that these analyses be carried out in the country itself so that results become rapidly available, the cost of maintaining a soil laboratory for Tonga might be too high. A possible solution might be to make an agreement with an international funding agency to install a small laboratory unit, under the supervision of an international research institute, for carrying out a restricted number of analyses (pH, organic material, NPK, and soil density). This laboratory might moreover have a double role, in the sense that it might not only monitor the pollution of soils and waters, but also be able to advise on the nutrients and fertilizers to be supplied.

Avoiding soil degradation - Large-scale commercial farming holds a number of side-effects which need to be properly managed to avoid land degradation: improper use of fertilizers and pesticides leading to soil and water pollution, compaction of subsoils, and surface erosion and runoff on non-protected sloping areas.

In an intensive cropping system mineral fertilizers must be added to compensate for the soil nutrient losses at harvest; their application can thus not be avoided. It is, however, in the interest of the farmer, for whom the costs of (imported) fertilizers comprise a major production cost, that the amounts applied are correct and in line with crop needs. The application of fertilizers in excess of crop requirements is, thus, both wasteful and environmentally harmful.

The total amount of fertilizers that a soil can absorb and make available to crops is determined by specific soil analyses like pH, content of organic material, cation exchange capacity and base saturation. During the crop cycle some of the available nutrients are taken up by the roots and later exported by the harvest. The fertilizers applied to the new crop are to compensate for the nutrients released by the soil to the crop root system. The approximate amounts of fertilizers needed for crop growth can be defined from soil analyses, which measure the nutrients stored in the root zone, and from plant uptake as defined in Table 5. These theoretical data should be adjusted for anticipated losses from leaching (more in highly permeable than in soils with lower infiltration rates), fixation by soil particles (mainly phosphorous), solubilisation (pH dependent), volatilisation (nitrogen) and runoff.

Most fertilizers applied in Tonga are in a mineral form and do not contribute to the build-up of organic material. Hence, the mineral fertilization should be completed with an organic component. In the absence of farmyard manure this should be achieved by a green manure which, in the case of Tonga, is often *Mucuna beans.*

Pesticides and related agrochemicals are meant to compete pests and diseases. Formerly, most of them where toxic to many other forms of soil life, but to date, many of them are biodegradable. The use of the toxic forms are in many countries forbidden by law (see Table 6), and this should also be the case in Tonga. The biodegradable pesticides are only harmful depending on their half-life time in the soil.

Soil compaction occurs under conditions where heavy farm machinery is too often used for field operations. In Tonga soil compaction is mostly observed in the subsoils of heavy clayey soils, as is the case for Vaini and Lapaha soils. Soil compaction can never be excluded completely in clayey soils but it can consistently be reduced by increasing the organic matter content in the profile, avoiding field operations when the solum is too wet, limiting the number of passings, deep ploughing, and using large soft tires so as to spread the full machine weight over a larger surface.

Sloping areas which have been denudated from their natural vegetation or that are left bare after harvest might be affected by runoff and erosion under intensive rain. The phenomenon is particularly visible on Fahefa, Vaini and Lapaha soils, rolling phase. Initially, surface erosion can be managed by protecting the soil with a vegetation mulch. In a more critical stage contour ploughing and strip cropping or terracing can be applied. Areas too much affected by erosion should be kept under forest or be converted into an agro-forestry type of land use.

5.3. Recommendations for Follow-up Actions

Availability and sharing of information - A national land use policy can not be based on assumptions, outdated observations and estimations, but needs firm basic and reliable information. Some of this information exists, though often outdated, but is not available. Basic reliable information is a prerequisite for the development of a sound national land use plan. If this information does not exist, it should be collected and be made available.

Likewise is the exchange of data sometimes difficult because agencies from different ministries are not used to collaborate and share data. Hence, it is recommended that the relevant ministries and departments should identify the data requirements to enable them to report on developments in relation to land, land use, land tenure, crop suitability and land management and to organise their own operations in accordance with acceptable norms. Agencies should, in addition, be made aware that data sharing does not affect their institutional power but is a prerequisite for an open dialogue and integrated approach to a more efficient land use in the country.

Value of land - Land in Tonga was traditionally considered a free gift without direct market value. Land is now becoming a relatively scarce commodity from which a benefit can be taken, either in terms of food or money. Hence, the competition for land is growing and conflicts can be expected between various users, either individuals or whole sectors of the economy. To avoid such conflicts there is an urgent need for planning and the development of an integrated land use policy which has overriding power over sector policies. All sector policies should be brought in line with this overall land policy.

Need for a more efficient, environment-friendly and performant agriculture - Tonga is faced with an important migration from outer islands and from rural areas in Tongatapu towards Nuku'alofa, the major commercial and cultural centre of the Kingdom. Hence, the number of food producers decreases in favour of net consumers. This development has resulted in a dramatic import of consumer goods, many of which can be produced in the country. This urges for a modernisation of Tonga's agriculture, and a more efficient and more performing crop production.

To increase agricultural outputs the former traditional slash and burn farming system has to be abandoned and modern farming techniques introduced. These should, however, not be exclusively based on the mechanisation of field operations, enlargement of field size, crop selection and use of agrochemicals, as is currently the case for squash-pumpkin production, as in the long run this production method will lead to a degradation of the land. The concepts of modern conservation agriculture should be analysed and studied for introduction in Tonga, whereby soil tillage operations could be minimised, the organic matter content of the soils be increased, and crop rotations be adapted so that fertilizer applications can be reduced and the use of pesticides gradually abandoned.

Sustainable production potential - The Kingdom of Tonga has a high potential for the production and marketing of both root crops for the local market, and tropical vegetable crops and fruits for off-season exports to New Zealand and Australia. The selection of crops and choice of cropland should be guided by land suitability investigations, in particular in the outer islands where there are still many opportunities. Due attention should also be paid to the growth of maize in support of the poultry industry in Tongatapu. Sustainable production should, obviously, be supported by scientifically sound fertilizer programmes (based on appropriate soil analyses) so to avoid over-fertilization and pollution of soils and ground water.

Technical and institutional support - The introduction of new production methods requires technical support and guidance. In this context the Government should, in collaboration with overseas assistance, make provision for appropriate scientific and technical support to local scientists and for the development of a proper extension service and training for farmers. This support should focus on modern sustainable production methods, modern environment-friendly farming techniques, the set up of a technical support unit for crop selection, and crop quality control, and on a proper infrastructure for export marketing and quality control. Conservation farming should be promoted into the farmer's community.

Modern farming and the use of fertilizers should be based on firm information on the quality of the soil and on optimal crop requirements. This needs proper laboratory data which, to date, do not exist in Tonga. As a first step in promoting correct fertilizer applications (and avoiding over-fertilization) it is recommended that laboratory facilities should be established as part of the Vaini research institute. The Government should search agreement with an international funding agency to install a laboratory unit, under the supervision of an international research institute, for carrying out a number of key analyses like pH, cation exchange capacity, organic material and NPK content (chemical soil properties), as well as soil texture and soil density (physical properties).

In the long run it will be necessary to install a research unit which should take care of the various aspects of crop production, crop selection and quality control of agricultural products, both for local consumption and export. This unit should at the same time supervise the quality of soils and groundwaters and, thus, become a useful tool for monitoring environmental hazards (see below).

Concern for land degradation and protection of the natural environment - The side effects of soil degradation from pollution and erosion will remain a matter of concern in a country where land use changes will be rapid and intense, but in order to take effective action a control system of environmental qualifyers has to be established, based on effective measurements and laboratory data (see above). The next step is then to define standards and to install norms for legal actions based on measured observations. In the same context, the access to land and current lease regulations should be adapted to sustainable modern forms of land use, in particular for avoiding soil mining, soil and water pollution, on-going deforestation, and erosion control.

Besides the human-induced environmental risks linked to modern cropping systems, Tonga is also vulnerable to a number of natural hazards. Due attention should therefore be given to a protection of the natural environment, and the role of Environmental Impact Assessments (enacted but not implemented in Tonga) should be recognised. In this environmental concern, forests and forest vegetation should play a major role in protecting coastlines, preserving terrestrial biodiversity and ground water quality, and breaking the damaging effects of cyclones and erosion.

The implementation of these conditions will require the adaptation of the existing, or enactment of a new legislation, with enforcement procedures and penalties included.

Land tenure and land use regulations - The Land Act (1988) is the basic law, overriding all other legislations, that defines the forms of access to land, land registration and land use. The Act has no proper by-laws and regulations to implement and enforce its legislation, and this creates confusion and ambiguities in conflict situations. In first instance its provisions should be updated, i.e. in revising and adapting the lease system to modern forms of land use. In the longer term, the review of the Land Act may indicate that more fundamental adjustments are required to land leasing in Tonga and its related tenurial framework. In this context it is recommended that the land law be reviewed and considered for updating as an interim measure, with appropriate adjustments, to bring it in line with current practices and requirements.

As a direct follow-up of the foregoing, it is recommended that the implementation requirements for the land law be reviewed and work processes redesigned to ensure that the relevant departments have the capacities and direction to implement their responsibilities in an appropriate manner.

Finally, and in the same line it is recommended that the review of the land law should consider the longer term issues of land policy and its administration and consider the possibility of calling for a more substantial review to bring land policy into line with current circumstances in Tonga.

Creation of an enabling environment for conflict resolution - To achieve these goals it is recommended that an enabling environment be created for (1) fastening the administrative procedures for the official lease contracts; (2) installing an independent commission to handle conflicts between lessees and lease holders on the quality of the land, and (3) for the critical issues which can not be observed *de visu*, as is the case for nutrient mining and subsoil compaction, make provision for soil sampling and proper interpretation of data in the case of critical soil conflicts.

Need for integrated planning - The Kingdom of Tonga has no established system of spatial planning. With no forward planning and no plans, there are no guidelines to assist decision making on either strategic or local development issues. There is also no structured identification of development or land use issues that may arise. It is recommended that awareness be created at institutional level explaining the need for planning and the methods to do so.

Another important issue in terms of planning is that the Kingdom of Tonga has no tradition and no experience in *integrated* planning. Many line ministries develop their own acts and regulations, but only on a strict sector basis. These regulations sometimes overlap and lead to confusion or conflicts with other sectors, viz. with other potential land users; not seldom is this confusion a reason for status-quo and stagnation. In this context, it is recommended that planning, land use and conflict resolution are treated in an inter-sectoral way. This includes as well the agriculture, which is probably one of the most commonly affected sectors, as other rural land users, and this should be a feature of any legislative developments in these fields.

Public awareness - Public awareness is an integral part of developing acceptable policies, and this should be recognised in the strategies relating to developing sustainable land use and land tenure policies. Awareness creation on environmental protection is well organised at students level. It is less successful at institutional and policy making level, as can be observed from the numerous infringements without legal actions related to beach mining, mangrove and forest cutting, forest encroachment, etc. As public awareness is also important in introducing concepts at institutional level of the need for planning, and in particular of integrated planning, it is recommended that strong action be taken in this domain.

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Technical Annex A:

GUIDELINES FOR LAND CAPABILITY AND LAND SUITABILITY EVALUATION IN TONGA

1. Introduction

Land capability deals with the production potential of the land and the management aspects related to this use potential in general terms, without consideration given to the specific requirements of each individual crop : subsistence food crops, vegetable cash crops, tree cash crops, pasture, forestry, leisure, residential and urban uses. Land suitability evaluation goes one step further in the assessment and deals with individual crops (cassava, pumpkins-squash, pawpaw trees,..), each of them with their own specific growth and production requirements. Both land capability and land suitability reflect thus different levels of detail in the assessment of the land use potential, and thus in terms of land use planning.

Both forms of assessment are based on a critical comparison of crop requirements on one hand and land properties on the other hand. The assessment uses a limiting factor approach, whereby ratings of limitations (or deviations from the optimal conditions) are described and rated according to the nature and degree of limitation. As climate can be considered as almost uniform over the area, the present assessment is mainly dealing with soil properties (except in cases where the climate influences the management). The result is a grouping of soils with properties which do not only meet growth conditions of the crop but also respond in a similar way to the same management. The criteria taken into consideration in this assessment are:

- climatic criteria: rainfall, water balance and growing period, temperature, drought and drought tolerance;
- soil criteria: soil texture, rooting depth, drainage, pH, salinity, nutrient status and nutrient requirements, surface erosion;
- landform factors: slope, flooding risk, and surface erosion.

The present preliminary assessment is largely based on the principles established by FAO (1976, 1983), Trangmar (1993) and Verheye (2007). The recommendations refer, however, to general crop evaluations which still need to be validated and refined by local agronomic experience. The ratings are based on physical environmental criteria only, and do not take into account factors like pest and disease susceptibility, and socio-economic factors like production costs, market prices or cultural preferences.This evaluation is limited to the island of Tongatapu.

2. Overall Land Capability of Tongatapu

Tongatapu is endowed with a subtropical climate with a relatively well distributed, though sometimes irregular, rainfall throughout the year and an average temperature between 22° and 30°C. Even in the so-called dry season there is enough rainfall to satisfy most of the moisture requirements for most crops.

The hazardous climate constitutes a moderate constraint for crop growth, mainly because of the irregularity of the precipitation, with very high rainfall periods alternating with the occurrence of dry spells. The rather frequently occurring hurricanes have an adverse effect on tree growth and development.

For Tongatapu as a whole, the land capability is mainly determined by soil characteristics. The best soils for root, vegetable and tree crop production are the Fahefa, Vaini soils and, to a lesser extent, the Lapaha soils for vegetable crops. Sopu soils are generally unsuitable for agricultural production, while the Nuku'alofa and Fatai soils require special measures of irrigation and drainage, respectively.

2.1. Capability for Root Crops

The root crops concerned refer in particular to: early and sweet yams, giant taro, American taro, Irish potato, sweet potato, and kava;

Fahefa and Vaini soils, which cover a major part of Tongatapu, have only minimal to slight limitations and present almost no restrictions for the production and management of root crops. Both soils may experience slight moisture deficits during dry spells. They are favourable for most methods of producing giant taro, taro, Irish potato, sweet potato and sweet yams. The clayey subsoils, paricularly in Vaini soils, provide a slight rooting limitation, but this can be overcome by a appropriate seedbed preparation and mounding. Early yams with a large taproot require some subsoil loosening during wet periods. Air temperatures are likely to restrict the growth of Irish potatoes to the cool season.

Lapaha soils, mainly covering at the eastern end of Tongatapu, have a relatively slow subsoil permeability and reduced aeration. This makes them more difficult to work when wet. They require higher mounding and deeper cultivation to obtain similar root crop production as compared to Fahefa and Vaini soils, particularly for sweet potato and early yam cultiation.

The *rolling phases of Fahefa, Vaini and Lapaha soils* are equally suitable for root crops as their flat variants, but need a more careful mangement to avoid topsoil losses by erosion. This applies particularly to potatoes and yams. Slope and erosion risk on these units may require soil conservation measures, such as contour cultivation, strip cropping, mulching, etc.

Fatai soils have limitations of imperfect drainage and flooding risks for short periods. Waterlogging during wet periods may inhibit crop growth and cause tuber rot, especially of yams (early and sweet) and potatoes (Irish and sweet). Drainage is required for optimum production, but is difficult, given the low position in the landscape. As a result, they are not well suited for yam and potatoes. Giant and American taro have higher tolerance to wetness, and their growth is less affected.

Nuku'alofa soils have severe limitations and are unsuitable for toot crop cultivation due to excessive drainage, seasonal moisture deficiency, and nutrient imbalances caused by high pH and calcium levels. In the somewhat deeper sandy loam variant the production of taro and yams is possible under irrigation, though the latter crop is sensitive to salt spray.

Sopu soils are unsuitable to root crops because of their high saline water table and flooding risk by seawater. It is recommended to retain them as mangrove swamps so as to preserve the ecological balance of the lagoons.

2.3. Capability for Vegetable Crops

This land utilisation type refers to vegetables including: cabbage, carrots, beans, cucumber, eggplant, onion, pumpkin-squash, tomato and watermelon;

Fahefa and Vaini soils have only minimal constraints for vegetable crop production. However, the clayey textures and firm subsoils, particularly of Vaini soils, suggest that mulching and deeper tillage might have a favourable effect on physical conditions and aeration, and on improved growth conditions and optimal yields of crops like carrots, onions, pumpkin/squash and watermelon. Under mechanised farming and monoculture cash-cropping there is a risk for soil compaction which can be avoided by subsoiling and the maintenance of high amounts of organic material in the surface layers. Under intensive cropping, adequate fertilizer applications are recommended.

Lapaha soils are less versatile than the Fahefa and Vaini soils for vegetable production. This is mainly due to their slower subsoil permeability and reduced subsoil aeration. Their higher clay content makes them also more difficult to work, particularly during and immediately after wet periods. Lapaha soils may require deeper cultivation to obtain similar production levels as Fahefa and Vaini soils, particularly for onions, pumpkin/squash, and water melon.

Vegetable production on the ***rolling phases of Fahefa, Vaini and Lapaha soils*** is comparable to the soils above, under the condition that due care is taken to avoid topsoil losses by erosion. This applies particularly for monocrop and row cultivation of cabbage, onions, tomatoes and water melon. Topsoil loss would bring clayey, firm, and lower fertility subsoils up into the rooting zone, resulting in a less favourable crop growth medium. The need for soil conservation measures makes these units therefore less versatile than their flat land equivalents. As with root crops, shortage of adequate water supply on rolling terrain may limit opportunities for irrigation of vegetable crops during the dry season.

Vegetable production on ***Fatai soils*** suffers from imperfect drainage and/or localised flooding. Water evacuation from these soils is moreover difficult because of their high water table and slow internal permeability. As a result, they are currently used for subsistence crops, banana and coconut plantations, rather than for vegetable production. The feasibility of using these areas as potential water-harvesting sites for storage and supply of water during drought periods might be worth investigating.

Nuku'alofa soils are generally unsuitable for commercial vegetable production because of their droughtness, exposure to salt spray, and nutrient imbalances caused by high pH and calcium contents. *Sopu soils* are unsuitable as well because of poor drainage, high saline water tables and flooding by seawater.

2.4. Capability for Tree Crops.

This land utilisation type includes mainly traditional crops like: banana, breadfruit, coconut, mango, orange, pandanus, paper mulberry, and vanilla, and coffee (robusta), some of which may turn out to become export crops.

Most soils of Tongatapu are suitable for this land use type. As with root and vegetable crops, ***Fahefa and Vaini soils*** are generally the best units, but for commercially- interesting yields an adequate fertiliser supply of NPK, and possibly trace elements, is recommended.

Lapaha soils are also generally favourable for tree crop production with slight limitations due to the presence of firm, heavy clay subsoils and poor aeration which may inhibit root penetration and restrict rooting volume. As such, tree crops are more susceptible to moisture deficits during dry spells, particularly during the establishment phase.

Tree crop production has similar perspectives on ***rolling phases of Fahefa, Vaini and Lapaha soils*** under condition that appropriate soil conservation measures are taken. These could include: mulching for moisture retention, across slope planting, or incorporation of grass strips between rows to reduce erosion risk. Any reduction in rooting volume due to surface soil erosion would increase their susceptibility to moisture deficits in the future.

On ***Fatai soils*** the choice of tree crops is restricted to those which tolerate temporary waterlogging for short periods, e.g. breadfruit, coconut, macademia and mango. Bananas and coconut plantations can as well be found on these soils, but they are less productive than on Fahefa or Vaini soils. Interrow drainage might improve growth conditions.

Coconuts and some citrus varieties are the only tree crops that might tolerate salt spray affecting ***Nuku'alofa soils***. Soil moisture deficits and nutrient balances due to alkalinity are major limitations for economic tree crop production.

Sopu soils are unsuitable for all tree crops because of poor drainage, high saline water tables and frequent flooding by seawater.

2.5. Capability for Pastoral Use

Areas of grassland used for grazing are limited on Tongatapu. Some stock is grazed around village sites. There are also a few areas of pasture under coconut plantations, mainly located in the northeast of the island, which are used for grazing of beef or dairy cattle.

In general, most soils of Tongatapu are well or moderately well suited to pastoral use, with only small areas having significant limitations. These are ***Nuku'alofa soils*** with limitations of seasonal moisture deficits, and ***Sopu soils*** with severe limitations of drainage.

2.6. Capability for Forestry

In general, the subtropical climate and soils of Tonga are favourabe for forestry. The volcanic ash soils have generally the minimal qualifications of tree growth. Good growth conditions exist for species such as red cedar (*Toona australis*), *Cedrela odorata*, teak (*Tectona grandis*), mahagony (*Swietennia macrophylla*) and *Eucalypthus* spp. at low and intermediate elevation.

However, the main limitation for forestry on such soils on flat to rolling land, and in Tongatapu in particular, is the competition for land with agricultural or urban uses.

In commercial timber exploitation the growth rate defines often the selection of trees for replanting. Volcanic ash soils are considered suitable for kauri (*Agathis robusta*), but growth rates are likely to be relatively slow compared to other species such as teak, red cedar and mahagony. Similarly, the regeneration of sandalwood (*Santalum yasi*) appears to be quite slow.

Current plantings indicate that growth rates of *Pinus caribaea* are better than those of the hardwood species on the higher less exposed areas. Because on these heights there is less competition from agricultural land use of this land, forestry development should mainly concentrate on these parts of the country, and in this context, *Pinus caribaea* may best suited to such sites, together with *Cedrela odorata*, teak, kauri and mahagony.

The droughtness, exposure to salt-laden winds, alkalinity and nutrient deficiencies of the sandy coralline soils generally make them unsuitable for most high-value timber trees. *Casuarina* spp. will tolerate such conditions, and is grown on such soils usually for shelter as windbreaks and/or fuelwood.

In a broader context, volcanic soils all over the archipelago are generally well suited to the production of important multi-purpose (timber, fuelwood, food) tree crops such as coconut, breadfruit, and paper mulberry (tapa). Coconut is by far the most important tree throughout the country. It is considered the tree of life because of its multiple uses as a provider of food (nuts and copra), shelter and timber.

Pawpaw and pandanus are well adapted as well to volcanic ash soils, as is the case for tree legumes such as *Leucaena* spp., *Albizzia* spp. or *Sesbania grandiflora*).

2.7. Capability for Urban Use

Nuku'alofa is a rapidly expanding city, and new and suitable areas for residential and commercial buildings are becoming limited. In any expansion of existing urban areas, a choice has to be made between to opportunity for residential and commercial uses, and the suitability and versatility of land for intensive agricultural use. Considerations on nature conservation and biodiversity protection should also be given attention. Urban development should therefore avoid, wherever possible, encroachment onto high-value agricultural soils, e.g. Faheva, Vaini and Lapaha soils, or nature reserves.

The main land factors which determine the value for urban use are: natural drainage, permeability for soak and septic tank pits, liability to surface or tidal flooding, and slope. The first three factors are important on Tongatapu, where sewage is mainly by septic tank. The presence of surface water around dwellings providing mosquito breeding grounds is also undesirable and, therefore, Sopu soils should not be used for urban development. This is corroborated by the presence of a natural mangrove vegetation, the destruction of which is probited by law. Hence, the recommended expansion of Nuku'alofa is towards the eastern direction of the town at a reasonable distance from the shoreline.

3. Land Suitability

Land suitability deals with the fitness of land for a defined use, e.g. a specific crop cultivated under a specific management system. A land suitability classification is a ranking of soils (or land units) based on the matching of crop growth and production requirements against major land properties. Because plant growth is mainly determined by climatic, soil and terrain factors, the criteria involved in this matching exercise rely to all three groups of these factors. Obviously, as different crops have different growth and production requirements, separate criteria have to be defined for each specific crop.

For each of these factors or crop requirements optimal growth conditions must be defined, as well as sub-optimal and marginal conditions. This is done in a rating scale with increasing intensity of constraints in the following order (Tables 1, 2 and 3):

- no limitation : the characteristic is considered (almost) optimal for plant growth;
- slight limitation: the characteristic is nearly optimal for the given land utilisation type; growth and productivity are affected for not more than 20% as compared to optimal yield;
- moderate limitation: the characteristic has a moderate influence on yield decrease, which is estimated between 20 and 50 %; benefits can still be made and the use of the land is still profitable;
- severe limitation: the characteristic is so important that the yield decreases by more than 50% as compared to the optimum and falls beyond the profitability level.

Land factors which meet the optimal growth conditions (e.g. which do not have any constraints) are considered very suitable to the crop. The more these land properties deviate from the optimal growth requirements, and thus rank in the suboptimal (slight limitations) and marginal (moderate limitations) conditions the less suitable the land is for that crop. Land properties which match with conditions considered as submarginal (severe limitations) for growth define the land as being unsuitable.

Factors which deviate from optimal conditions might in some cases be corrected. In this case one can compare the actual and future or potential suitability of the land for a given crop. The identification of land limitations opens sometimes perspectives for land improvements. It should, however, be noted that some factors can be corrected while others do not. Most climatic limitations can technically not be corrected, except water shortage (by irrigation). Some of the soil factors can technically be corrected (soil dranaige), others do not (texture for example).

Tables 1, 2 and 3 illustrate the growth requirements for three representative crops in Tonga. These requirements are defined on the basis of international literature and research reports, but do not take into account the specific nature of local crop species grown in the country. These tables should therefore be considered as guidelines which need to be tested in the country before being used as assessment criteria.

Land characteristic	**Degree of limitation**			
	No	**Slight**	**Moderate**	**Severe**
Climatic criteria				
Annual precipitation (mm)	1000-24000	600-1000 >2400	500-600	<500

Number of months with P < 50mm	1-4	4-6 <1	6-7	>7
Mean annual temperature (°C)	20-30	16-20 >30	12-16	<12
Minimum temp. in grow. season	>16	10-16	5-10	<5
Terrain criteria				
Slope (%)	<4	4-8	8-20	>20
Physical soil criteria				
Texture (Clay content)	35-50	50-60 25-35	60-80 <25	>80
Gravel content (%)	0-5	5-10	10-20	>20
Soil depth (cm)	>100	60-100	20-60	<20
Drainage	Good	Mod-Go	Mo-Po	Poor
Flooding risk	None	Rare	Mod	High
Chemical / Fertility soil criteria				
Cation Exch. Cap (me/100g soil)	>16	10-16	<10	-
Base saturation (%)	>35	25-35	<25	-
Sum of bases (me/100g soil)	>8	5-8	<5	
pH (water)	5.8-7.0	7.0-7.5 5.8-5.0	7.5-8.2 4.8-5.0	>8.2 <4.8
Organic material (OC %)	>1.5	0.8-1.5	<0.8	-
Electrical Conductivity (dS/m)	0-2	2-3	3-4	>5

Table 1: Crop growth requirements for cassava.

Land characteristic	**Degree of limitation**			
	No	**Slight**	**Moderate**	**Severe**
Climatic criteria				
Annual precipitation (mm)	1000-2000	800-1000 >2000	600-800	<600
Mean annual relative humidity (%)	50-80	50-85 25-50	>85 <25	
Mean annual temperature (°C)	20-28	15-20 28-34	10-15 34-38	<10 >38
Mean temp. coolest month (°C)	>16	13-16	8-13	<8
Terrain criteria				
Slope (%)	0-3	3-8	8-15	>15
Physical soil criteria				
Texture (Clay %)	30-45	45-60	60-80	>80

		20-30	<20	
Gravel content (%)	0-8	8-15	15-30	>30
Soil depth (cm)	>100	60-100	25-60	<25
Drainage	Good	Moder	Imperf Excessive	Poor
Flooding risk	None	None	Slight	Moder
Chemical / Fertility soil criteria				
Cation exch. cap. (me/100g soil)	>16	8-16	5-8	<5
Base saturation (%)	>35	15-35	<15	
Sum of bases (me/100g soil)	>15	8-15	5-8	<5
pH (water)	6.0-6.8	5.5-6.0 6.8-7.5	5.0-5.5 >7.5	<5.0
Organic material (OC%)	>1.5	0.8-1.5	<0.8	
Electr. conductivity (dS/m)	0-2	2-3	3-4	>4

Table 2: Crop growth requirements for papaya.

Land characteristic	Degree of limitation			
	No	**Slight**	**Moderate**	**Severe**
Climatic criteria				
Annual precipitation (mm)	800-1500	600-800 1500-1700	500-600 >1700	<500
Number of months in growth cycle with P<50mm	0	1	2	>2
Relative air humidity at harvest	<65	65-80	>80	
Mean temperature (°C) in growth season	22-26	20-22 26-32	16-20 32-40	<16 >40
Mean minimum temp (°C) of growing season	15-20	10-15 20-24	7-10 >24	<7
Sunshine hours in devel. stage	5-8	<5 >8		
Sunshine hours in matur. stage	>6	<6		
Terrain criteria				
Slope (%)	<5	5-8	8-16	>18
Physical soil criteria				
Soil texture (Clay %)	40-60	>60 30-40	15-30	<15
Gravel content (%)	0-8	8-15	15-40	>40
Soil depth (cm)	>80	50-80	25-50	<25
Drainage	Good	Moder	Imperf Excessive	Poor
Flooding risk	None	Slight	Moder	Frequent

Chemical / Fertility soil criteria				
Cation exch.cap. (me/100g soil)	>16	10-16	<10	
Base saturation (%)	>50	35-50	20-35	<20
Sum of bases (me/100g soil)	>8	5-8	<5	
pH (water)	5.5-7.2	4.8-5.5 7.2-8.2	4.5-4.8 8.2-8.5	<4.5 >8.5
Organic material (OC%)	>2.5	1.5-2.5	1.0-1.5	<1.0
Electr. conductivity (dS/m)	0-2	2-4	4-8	>8.0

Table 3: Crop growth requirements for sweet potatoes.

There are several procedures to interprete the rating scale but, in general, the ranking into classes is based on a combination of the most important constraint (law of the minimum) and the number of constraints (the more constraints, the more the suitability rating is downgraded). In the FAO system five suitability classes can be differentiated:

- Class S1: Highly suitable land, corresponding to land without significant limitations for sustained use, or with only minor constraints that do not significantly reduce productivity and benefits. In other words, land with not more than 3 or 4 slight limitations, with expected yields between 80 and 100% of the maximal yield.
- Class S2: Moderately suitable land, corresponding to land that has constraints which, in aggregate, are moderately severe for a sustained given use; the constraints will reduce productivity or benefits and/or increase inputs to the extent that the overall benefits, although less than for class S1, will remain attractive. In other words, class S2 land has more than 3/4 slight limitations and/or no more than 3/4 moderate limitations. Yields are expected to range between 50/60 and 80 % of the possible optimal production.
- Class S3: Marginally suitable land. Limitations in aggregate are severe for a sustained given use, and benefits further decrease or management inputs have to be increased consistently. Profitability is nevertheless still guaranteed. In other words, S3 land has more than 4 moderate constraints and/or no more than 2 severe limitations which can technically be reclaimed and that do not exclude the justified use of the land.
- Class N: Unsuitable land. Land which has more than 2 severe constraints and that has at least one limitation that can technically not be reclaimed. Under certain conditions it might be needed to subdivide this class into two subclasses: N1: (unsuitable land that can not be reclaimed with the current knowledge and at an acceptable cost, but that might be reclaimed later) and N2: definitely unsuitable land.

The results of the matching procedure between crop requirements and the inherent properties of the soils of Tongatapu are summarized in Tables 4, 5 and 6.

Soil type*	Crop							Comments
	Giant taro	**Taro**	**Irish pota**	**Swe potat**	**Earl yam**	**Swe yam**	**Kava**	
No special management required:								
Fahefa	S1	S1	S1	S1	S2	S1	S1	Nutrients, moisture
Vaini	S1	S1	S1	S2	S2	S1	S1	Nutrients, texture
Lapaha	S2	S2	S2	S3	S3	S2	S3	Subsoil permeability
Fatai	S2	S2	SS	N	S3	S3	S3	Drainage

Usually practicable without special management								
Vaini low	S2	S2	S3	S3	S3	S3	S3	Nutrients, wetness
Lapaha low	S2	S2	S3	S3	S3	S3	S3	Subsoil perm., wetn
Nuku'(Lsa)	S3	S3	N	N	S3	S3	N	Drought, alkalinity
Production only with special measures (mulching, erosiun control, ...								
Fahefa rol	S2	S2	S3	S3	S3	S3	S2	Nutr., moist., slope
Vaini rol	S2	S2	S3	S3	S3	S3	S2	Nutr., text., slope
Lapaha rol	S2	S2	S3	S3	S3	S3	S3	Subsoil perm., slope
Nuku'(Sa)	N	N	N	N	N	N	N	Drought, salt, alkal.
Sopu	N	N	N	N	N	N	N	Drainage, flood, salt

* Vaini low, Lapaha low: low-lying phase of Vaini and Lapaha series; Nuku'(Sa) and Nuku' (Lsa) : Sandy and loamy sand phases of Nuku'alofa series; Fahefa rol, Vaini rol and Lapaha rol: sloping phase of Fahefa, Vaini and Lapaha series.

Table 4: Suitability evaluation for root crops in Tongatapu
(adapted from Trangmar, 1993).

Soil type*	**Crop**							**Comments**
	Cabbage	**Carrot**	**Beans**	**Cucumber**	**Egg plant**	**Squash**	**Watmelo**	
No special management required:								
Fahefa	S1	S1	S1	S1	S1	S1	S1	Nutrients, moisture
Vaini	S1	S2	S1/2	S1/2	S1/2	S2	S2	Nutrients, texture
Lapaha	S2	S3	S2	S1	S2	S3	S3	Subsoil permeability
Fatai	S3	S3	S3	S2	S3	S3	S3	Drainage
Usually practicable without special management								
Vaini low	S3	S3	S3	S2	S3	S3	S3	Nutrients, wetness
Lapaha low	S3	S3	S3	S2	S3	S3	S3	Subsoil perm., wetn
Nuku'(Lsa)	N	S3	N	S3	S3	N	S3	Drought, alkalinity
Production only with special measures (mulching, erosion control, ...								
Fahefa rol	S3	S2	S2	S2	S2	S2	S3	Nutr., moist., slope
Vaini rol	S3	S2	S2	S2	S2	S2	N	Nutr., text., slope
Lapaha rol	S3	S3	S2	S2	S2	S3	N	Subsoil perm., slope
Nuku'(Sa)	N	N	N	N	S3	N	N	Drought, salt, alkal.
Sopu	N	N	N	N	S3/N	N	N	Drainage, flood, salt

* Vaini low, Lapaha low: low-lying phase of Vaini and Lapaha series; Nuku'(Sa) and Nuku' (Lsa) : Sandy and loamy sand phases of Nuku'alofa series; Fahefa rol, Vaini rol and Lapaha rol: sloping phase of Fahefa, Vaini and Lapaha series.

Table 5: Suitability evaluation for vegetable crops in Tongatapu
(adapted from Trangmar, 1993).

Soil type*	**Crop**							**Comments**
	Banana	**Bread fruit**	**Coconut**	**Coffe**	**Mang**	**Pape Mulb**	**Vanill**	

No special management required:								
Fahefa	S1	S1	S1	S1	S1	S1	S1	Nutrients, moisture
Vaini	S1	S2	S1	S1/2	S2	S1/2	S1/2	Nutrients, texture
Lapaha	S2	S3	S2	S2	S3	S2	S2	Subsoil permeability
Fatai	S3	S3	S3	S3	S3	S3	S3	Drainage
Usually practicable without special management								
Vaini low	S3	S3	S3	S3	S3	S3	S3	Nutrients, wetness
Lapaha low	S3	S3	S3	S3	S3	S3	S3	Subsoil perm., wetn
Nuku'(Lsa)	N	N	S2	N	S3	S3	N	Drought, alkalinity
Production only with special measures (mulching, erosiun control, ...								
Fahefa rol	S1	S2	S1	S2	S2	S3	S2	Nutr., moist., slope
Vaini rol	S2	S2	S2	S2	S2	S2/3	S2	Nutr., text., slope
Lapaha rol	S2	S3	S2	S3	S3	S3	S3	Subsoil perm., slope
Nuku'(Sa)	N	N	S3	N	N	N	N	Drought, salt, alkal.
Sopu	N	N	N	N	N	N	N	Drainage, flood, salt

* Vaini low, Lapaha low: low-lying phase of Vaini and Lapaha series; Nuku'(Sa) and Nuku' (Lsa) : Sandy and loamy sand phases of Nuku'alofa series; Fahefa rol, Vaini rol and Lapaha rol: sloping phase of Fahefa, Vaini and Lapaha series.

Table 6: Suitability evaluation for tree crops in Tongatapu
(adapted from Trangmar, 1993).

4. Conclusions

The suitability evaluation for crops in Tonga shows that there is scope for a wide **diversification of agricultural products**, both for export and for meeting the local markets. This refers in the first place to tropical fruits, for which Tonga has a high potential. Papaya (paw-paw), eggplants and mango are already locally grown, but their production can be increased and improved. Other fruit trees like ramboutan, lychee, soursop, etc. have good potential for export as well, both as **fresh fruits** or processed. In the first case the producers will have to cope with the very strict quality regulations imposed by importing countries (fruit fly in particular), and this will need the structural support of the Ministry of Agriculture. A reasonable alternative would be to process the fresh products into juices.

Additional crops to take into consideration are (robusta) coffee, vanilla and cacao. A small plantation of Robusta coffee is already in place on Tongatapu island, but it is believed that a good potential for these products exists also on other islands. The advantage of these commodities is that they can be harvested and shipped as dry products. A similar situation occurs for the production of **vanilla** which is traditionally grown in the Kingdom and for which the pollination technology is known.

Annex 1:

ITINERARY AND DETAILS OF ACTIVITIES

Monday July 7, 2008: Travel De Pinte (Start of mission, dep. 9.03) - Brussels (arr. 10.15) by train; and Brussels (dep.12.00) - Rome (arr. 14.20) by AZ 159.

Tue July 8: Technical briefing at FAO-HQ/ NRLA : F. Nachtergaele, R. Biancalani, P. Munro-Faure and S. Bunning. Data collection Tonga project and LADA approach to land degradation. Review of documents.

Wed July 9 : Travel Rome (dep. 9.15) by AZ 0202 to London (arr.11.25 - dep.16.15) by NZ 0001 to Auckland (arr. Friday 05.15).

Fri July 11: Day rest in Auckland. Auckand (dep. 22.10) by NZ 0868 to Nuku'Alofa (arr. Saturday 02.00).

Sat July 12 and Sun July 13: Document consultation ADB project on Urban Planning for Tonga.

Mon July 14: Morning: Meeting Vahai'Lui (FAO contact person), Tevita Malolo (national consultant, Min. of Lands, Survey, Natural Resources and Environment). Establishment of work calendar and technical meetings. Visit Meteorological Office, and meeting 'Ofa Fa'anunu (Director of Meteoroly).
Afternoon: Introductory meeting at Ministry of Lands, Survey, Natural Resources with Sione Naikalasikau Halatuituia (CEO Ministry of Lands), 'Asipeli Palaki (Deputy-Director of Environment/ Deputy Secretary of Ministry of Lands) and Tukua Tonga (Director of Urban Planning). Visit Department of Environment and meeting Ms. Atelaite Lupe Matoto (Senior Environment Officer, Dept. of Environment and Natural Resources).

Tue July 15: Visit National Agricultural Research Center in Vaina. Meeting Viliamni T. Manu (Deputy-Director Agricultural Research, Researh and Extension Division, Min. Agriculture, Forests, Food and Fisheries) and Manaia Halafihi (Chief Agronomist). Field visit eastern part of Tongatapu Island; coastal erosion; local cropping systems.

Wed July 16: Data collection on soils and environmental issues. Document reading.

Thu July 17 : Data collection from GIS section (maps), Min. Lands. Meetings and discussions of environmental issues with Dept. of Environment.

Fri July 18: Data collection. Document reading. Discussions on cropping patterns and land management with Deputy-Director Agric. Research.

Sat July 19 and Sun July 20: Document reading.

Mon July 21: P. Faure-Monroe (FAO-HQ, LandTenure) joins the mission. Review of project findings. Discussion on land lease issues. Meeting Siope Lomu, Chief Land Valuer.

Tue July 22: Morning: Field visit of eastern Tongatapu Island. Various cropping patterns. Coastal erosion Kanokupolu village. Tourist development Liku'alofa Beach Resort, Kanokupolu. Meeting Minoru Nishi, Commercial farmer. Afternoon: Meeting Survey Division and Land Registration Division.

Wed July 23: Meeting at Dept. of Environment, Ms. Tupe Samani, Conservation Officer. Discussing Sustainable Land Management Project. Meeting CEO Min. Lands and Director Urban Planning. Document collection and reading.

Thu July 24: Collecting and consulting documents at Dept. Environment. Strategic Development Plan SDP8 and Environmental Impact Assessment Act.

Fri July 25: Trying (in vain) contacts with Ministry of Agriculture on use of fertilizers and pesticides. Field visit to vanilla, nonu and kava fields, mangrove protection. Discussions with FAO mission on Forestry Legislation. Document reading.

Sat July 26 and Sun July 27: Document reading and streamlining reports of national and international consultants.

Mon July 28: Trying (in vain) contacts at Ministry of Agriculture on data for fertiliser and pesticide uses. Field visit coastal erosion features. Collection of missing documents on legislation.

Tue July 29: Morning : Invited guest at King's Coronation Celebration. Afternoon: Wrap up meeting with CEO Ministry of Lands. Final arrangements for reporting with National Consultant. Meeting M. Aru and R. Sands, FAO Forest Policy consultants.

Wed July 30: Travel Nuku'alofa (dep. 11.35) - Auckland (arr. 13.25) by NZ0067. Day rest in Auckland. Travel Auckland (dep. 22.30) - London (arr. 11.00 Thursday) by NZ 0002.

Thursday July 31: Cont'd travel London (arr. 11.00; dep. 14.40) - Brussels (arr. 16.50) by BD 0151. Train Brussels (dep.17.45) - De Pinte (arr. 18.56). End of field mission.

Friday August 1 till Saturday August 16: Report writing

Annex 2:

PERSONS CONSULTED DURING THE MISSION

TONGA Ministry of Lands, Survey, Natural Resources and Environment

SIONE NAILASIKAU HALATUITUIA : CEO, Ministry of Lands, Survey, Natural Reources and Environment.
SELESI FOTU: Principal Registration Officer.
SIOPE LOMU: Chief Land Valuer.
GRAHAM MALEI: Surveyor.
ATELAITE LUPE MATOTO: Senior Environmental Officer, Dept of Environment and Natural Resources.
TEVITA MALOLO: National Consultant/ Counterpart.
'ASIPELI PALAKI: Deputy-Director of Environment and Deputy-Secretary of Ministry of Lands.
'ALIKISANITA PONGI: Senior Surveyor.
TUPE SAMANI (Ms): Conservation Officer, Dept. of Environment and Natural Resources.
TOKUA TONGA: Director of Urban Planning.

TONGA Ministry of Agriculture, Forestry, Food and Fisheries

HALAFIHI MANAIA: Chief Agronomist, Research and Extension Division, Agricultural Research Station, Vaina.
WILLIAM T. MANU: Deputy Director, Research and Extension Division, Agricultural Research Station, Vaina
VAHAI' LUI: FAO Contact Point in Tonga

TONGA Ministry of Transport

'OFA FA'ANUNN: Director of Meteorology, Tonga Meteorological Service

Other People in TONGA

DAVID COLLINS : Economic Statistics Consultant IMF.
PESETI MA'AFU: Managing Director Liku'alofa Beach Resort.
MINORU NISHI : Commercial Farmer, Director of Nishi Trading Cy.
BRUCE PEARCE: Field Advisor Plasma Biotec Solutions Ltd, Auckland, New Zealand.

FAO

M. ARU: Forest Policy Consultant, Appia
R. BIANCALANI : Technical Officer LADA Project, NRLA, HQ Rome
S. BUNNING : Technical Officer LADA Project, NRLA, HQ Rome
P. MUNRO-FAURE : Chief Land Tenure and Management, NRLA, HQ Rome
F. NACHTERGAELE : Technical Officer Soils and Land Evaluation, NRLA, HQ Rome
R. SANDS: FAO Forestry Consultant in Tonga

Annex 3:

TERMS OF REFERENCE
FOR THE RETIRED FAO CONSULTANT

Under the overall supervision by the FAO Subregional Representative for the Pacific based in the Subregional Office for the Pacific (SAPA), Samoa and in close collaboration with the FAO Land Tenure and Management Unit (NRLA) in FAO Headquarters, Rome, the Consultant will undertake the following responsibilities:
- identify areas most at risk of land degradation;
- based on identification of land degradation risk areas, formulate land capability and soil suitability maps describing soil type and vulnerability in soil areas affected by land degradation;
- formulate a database or guidebook on agricultural activities best performed in an area based on land capability and soil suitability framework;
- prepare a public awareness plan of action for resource material developed as indicated in the point above;
- design of appropriate policy framework for sustainable land use for the Department of Environment as a basis for issuance of short-term leases;
- develop a land use policy promoting sustainable practices, targeting short-term leases for commercial agricultural purposes;
- the Consultant reports to the Minister for Lands, Survey, Natural Resources and Environment. The Minister is also the Chair of the Cabinet Committee on Climate Change.

At the completion of the consultancy the International Consultant is expected to deliver the following:
- set of graphs demonstrating high risk areas of land degradation;
- completion of maps illustrating soil suitability in risk areas;
- guidebook on appropriate agricultural activities against soil suitability;
- completion of plan of action for public awareness;
- draft land use policy for consultation;
- submission of a mission report to FAO.