Land Resource Planning Study
Western Samoa

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Final Report

ANZDEC Limited Consultants
in association with
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EXECUTIVE SUMMARY

1. OVERVIEW

Having agreed with the United Nations Development Programme (UNDP) and the Government of Western Samoa to act as Executing Agency for the Land Resource Planning Survey covering Western Samoa, the Asian Development Bank (ADB) awarded the contract in April 1989 to ANZDEC Ltd of Auckland, New Zealand in association with the Division of Land and Soil Sciences, Department of Scientific and Industrial Research (DSIR), New Zealand.

The contract required the consultants (working in cooperation with the Treasury Department, Department of Lands and Survey (DLS) and Department of Agriculture, Forests and Fisheries (DAFF) to:

- Update the 1963 (A.C.S. Wright) soil survey of Western Samoa by additional field survey, soil sampling and analysis, physiographic reclassification, classification according to Soil Taxonomy and land capability interpretation.
- Determine current land use from aerial photographic and field interpretations.
- Plot cadastral boundaries between Government, WSTEC, freehold and customary land (but no internal boundaries).
- Produce landuse maps, soil maps and land capability maps at 1:50 000 scale.
- Complete an agricultural production and economic analysis.
- Establish a P.C.-based Geographical Information System (G.I.S.) with databases covering the whole country on the spatial themes of topography, soils, land use/tenure and land capability.
- Train counterpart staff in the range of skills covered by these project activities.

2. IMPLEMENTATION

The project office was established in DLS, Apia in late April 1989.

Over the following 7 months:

- The soils of Upolu, Savai'i and smaller islands were reappraised by field surveys and new draft soil maps, with new physiographic and taxonomic legends completed.

- The record of land use was updated and re-interpreted from aerial photography and field information.
- The land tenure boundaries were plotted from DLS and DAFF records (Government, WSTEC and Freehold).
- Land capability draft maps were prepared, with legend from soil, climatic and other data.
- The required maps were produced as 6-sheets for each theme at a scale of 1:50 000 (18 maps, total).
- The GIS hardware, software and databases were established to operational level for these themes.
- Overseas Fellowships (New Zealand) were completed for two GIS trainees and two Land Use Planning trainees.
- A concluding seminar presentation was held in Western Samoa during November.
- The Final Report and Maps were delivered to the Western Samoa Government and ADB in December 1989.

Staff of DLS and DAFF were to be given training in soil survey, cartography and G.I.S. aspects in February/March 1990.

All project tasks were successfully completed on time by the allotted resources.

There was full cooperation from Treasury Department, DLS and DAFF and no major problems arose affecting personnel, liaison, equipment or management.

Every effort was made by the consultants to link in with comparable activity under the broader Western Samoa Development Programme with a view to the future use of the GIS information.

3. CONCLUSIONS

(a) It is felt that the GIS system created is unique in having broad yet detailed countrywide coverage of land-based themes, to a high degree of accuracy. However, further work will be essential to upgrade and update the data bases as new data becomes available. The only successful approach is a dynamic one, with upgrading work being carried out as a matter of course.

(b) The on-going training aspect: it is seen as essential that there be no prolonged gaps in the cartographic/GIS training. Such systems require a high level of software and graphic design understanding to achieve results with community-wide impact.

(c) System extension: there are many themes, some with conventional spatial expression (e.g. the cadastre) and others (such as agricultural statistics) needing development to suit them to the GIS environment. These should be carefully examined for addition to the suite of themes already on the system. Although PC-based, the system is sufficiently robust to accommodate such extensions. Further, provision exists on the system to produce supportive texts, although large-scale growth in this direction could best be served by additional (and compatible) word processors in the implementing agencies.

(d) The PC-based GIS system developed for Western Samoa is highly relevant for other Pacific Island nations and, if replicated in these countries, will form the basis of a regional GIS. Western Samoan staff trained under this TA will be able to participate in this development as trainers.

4. RECOMMENDATIONS

The Consultants recommend that:

(i) Any Technical Assistance extension effort focus on the training, system support and graphic design aspects of the GIS.

(ii) DLS be encouraged to move to a computer-compatible cadastral recording system and to devise and implement pilot studies for conversion to computer recording, using the current GIS as a "starter" system.

(iii) All avenues be continually explored to extend the GIS to image processing capability. This will greatly increase the system's usefulness across a wide range of activity (intertidal/reef zone studies, environmental studies, shallow-water bathymetry, biomass evaluation, vegetation/soil themes, etc) through access to high-resolution (e.g. SPOT or airborne) imagery.

(iv) The Western Samoa Government be encouraged and assisted to publicise and market the GIS capabilities to encourage a broader range of spatial themes and to develop strategies to make the GIS products available and applicable at village level.

(v) Efforts be directed towards duplicating the GIS system in other Pacific countries.

SECTION 1. BACKGROUND

1.1 THE LAND RESOURCES PLANNING STUDY

1.1.1 Objective

The objective of the technical assistance is to provide Western Samoa with a comprehensive database for planning the optical and sustainable development of the country's land resources.

1.1.2 Outputs

The technical assistance will provide:

(a) computer hardware and software for operating a Geographic Information System.

(b) thematic maps of 1:50,000 covering

(i) soils
(ii) land use
(iii) tenure
(iv) basic topography
(v) land capability

(c) training in spatial data input and GIS manipulation and output.

(d) training in land use planning.

(e) classification of soil according to soil taxonomy, the FAO classification and links to the soils of American Samoa.

(f) economic analyses of alternative land use enterprises and the application of cost benefit analysis to land protection uses.

1.1.3 Use of Outputs

A technical report and a final seminar will be directed towards the use of project outputs.

There is the potential to use the land information and the maps in a number of ways.

1. Extension officers advising producers in their districts can have the map themes printed out. The financial analyses can be used to assist farmers choose options based on the soils and land capability shown for the area.

2. Research staff can use the soil taxonomy classification to examine suitable

sources of overseas research information, that also uses the soil taxonomy classification, which could have application in Western Samoa.

3. Advisers and planning staff developing programmes of support services or projects promoting desirable land use, can use the thematic maps and manipulate the economic data to suit land capability.

1.2 WESTERN SAMOA : AN OVERVIEW

1.2.1 Physical

The physical resource base of Western Samoa is the subject of this report. On an area of 2831 sq. km are a range of soils and climatic patterns which determine the underlying ability of the land to produce. Areas vary considerably from those that are highly fertile to those which have severe limitations for use other than protection. It is a resource base that needs careful management and husbandry.

1.2.2 Economic

For 1988 export receipts covered 20 percent of import costs. Private remittances financed 47 percent and tourism 21 percent. Development assistance grants and loans for projects more than offset the remaining deficit allowing a boost to international reserves (Central Bank of Western Samoa, 1988).

A review of performance from 1983-1987 (Western Samoa Socio- Economic Situation, Development Strategy and Assistance Needs, Round Table Meeting Geneva October 1988) indicates improvement in several areas, including Government revenue, inflation control, and net foreign assets. Foreign debt and debt servicing as a percentage of export have remained at similar levels over the period. Imports and the trade gap, however, have grown at rates greater than those for exports. The agricultural products index has remained below the 1982 level.

1.2.3 Social

A population of just over 160,000 is growing at a net 0.6 percent, the product of high national growth rates (2.9 percent) and high emigration levels. This creates a high dependency ratio, with large numbers of young persons and old people for the working age population to support. It also leads to a loss of skilled and able people constraining domestic output. Emigration levels however sustain the level of remittances coming into the country.

The social pattern provides for a high level of order and social cohesion. Extended family units provide for many social services, the council of *matai* (traditional leaders) provide for village order, and women's committees undertake health and welfare programmes. The balance favours order and the *status quo* over change. The pressure for change may be reflected in the level of land disputes brought before the Land and Titles court. It may also be reflected in the level of migration.

1.2.4 Review of Land Based Activities

Negative growth rates in GDP in the early 1980's resulted from declining export volumes (cocoa and bananas) and depressed commodity prices (copra and cocoa).

From 1983 some growth has occurred. The commencement of operation of the coconut oil mill contributed to a significant rise in the value of exports. Results in other years have reflected international price movements.

Replanting in the 1960's and 70's contributed to the basic stock of coconut plantations. This reversed the trend of declining production so that in years of good prices in the 1980's an output of greater than 25,000 tons of copra equivalent has been achieved. However, the low productivity of mono-cropped local tall coconuts has made that output very price sensitive. New hybrid coconuts have established their ability in trial plantings to produce at 2 and 3 times the level of tall coconuts.

The significant area occupied by senile coconut palms is a constraint to re-development and increased productivity.

Cocoa acreages established in the 1940's continue to decline in productivity and the level of replanting has only reached significant levels in the 1980's. Their contribution to overall production is unclear at this point particularly in view of the uncertainty about remaining production from old stands. From 1983-1989 total production declined 26 percent.

Taro has become a mainstay of the export sector and the only area of growth in output. It gives high returns but the sustainable level of production in the long term needs investigation.

Livestock production data is limited but production growth has not been sufficient to curtail increases in imports of meat and dairy products.

However, it is probably unwise to judge the performance of the livestock sector in terms of such macro economic criteria. The appropriate level of livestock production is better judged in terms of efficient use of land and labour resources relative to crop and forestry enterprises.

The forestry sector output has declined from 1985 due to problems with equipment at the SFP mill. However, planting targets for the reforestation programme have generally been achieved and provide the basis for enhanced future output.

Given price constraints for the main commodity outputs diversification into alternative crops requires attention and programmes are in place to promote the output of a range of fruit crops with suitable market opportunities.

SECTION 2. LAND USE IN WESTERN SAMOA

2.1 INTRODUCTION

The project team's assessment of the availability of spatial land use data revealed that no detailed spatial records were kept which could have formed the basis for mapping requirements and GIS database. Only the 1: 20 000 Topographical Series, (NZMS 174) had an accurate spatial framework covering the country which included land use information in the form of vegetative cover with crop symbols. It was decided to adopt this as a base which could be improved within the required timeframe of the project.

2.2 METHOD

Firstly, the Project Cartographer, who has extensive topographical, land use and photo-interpretive mapping experience, examined the vegetative cover delineated on the 1: 20 000 maps and compared it with recent aerial photographic coverage of Western Samoa at 1: 50 000, 1: 20 000 and 1: 13 000 scales ranging in age from 1981 to 1987. He was able to redefine the interface between forest, pasture or bare land and coconut plantings and to distinguish other tree crops such as banana and plantation forest.

Having completed mark-up of the land use polygons by aerial photo-interpretation, meetings and a field demonstration were arranged with DAFF management and agricultural field officers to augment this data. Sets of maps were distributed for field update following instruction on requirements. When these maps were returned, usable data was incorporated into the master compilation derived from aerial photo-interpretation.

Time did not permit extensive field-checking of the data, although some were supplied by the soil scientist, and in any case accuracy standards had to be relaxed as the extent of crops and underplanting of tree crops cannot be accurately verified from vantage points due to the height of tree and coconut crops.

2.3 RESULTS

The land use information must be regarded as interim. As with all GIS systems, decisions must be made to complete database coverage with the best data available or to extend the programme to improve it. It was imperative to complete the project on time and reliance is placed on an on-going programme to refine the data as new information comes to hand from land surveyors, agriculturalists, foresters and others working in an area. The interfacing land use boundaries marked on the topographical maps reflected map revisions of 1: 20 000 sheets spread over the past 15 years. With the transient nature of some tree crops such as banana, the age limitations of coconut and cocoa and the cutting of indigenous forest, it is inevitable that the land use data base contains some errors of small detail. However, it is adequate as a country-wide planning base in conjunction with the land tenure, soil and land capability covers.

2.4 FUTURE WORK

Clearly, strenuous effort will be needed to improve this data base through an organised programme involving professional field officers of the implementing agencies. It is suggested that land-based students (e.g. agriculturalists) could play a useful role in data update and improvement as part of their curricular studies.

SECTION 3. SOILS OF WESTERN SAMOA

3.1 INTRODUCTION

Western Samoa has a total land area of 699 000 acres (2831 square km) consisting of the more densely populated Upolu Island (1123 square km) and Savai'i Island (1708 square km) with smaller islands of Manono, Apolima and a number of smaller off-shore islets.

The country relies heavily on agricultural and forestry production, both for exports (copra, cocoa, taro, ta'amu and timber) and for local consumption. It is therefore appropriate that more detailed soil information with modern classifications and soil interpretations is available so that the most suitable soils can be used for crop production and land protection measures can be taken for areas that should be retired.

This section describes the soils and their classifications with more detailed information listed in Appendices 1 to 5. Background on soil classification and, in particular, Soil Taxonomy can be found in the Training Manual that was produced separately as part of the present study.

3.2 METHODS

3.2.1 Background material

A comprehensive soil survey with land use interpretation by Wright (1963) was used as the basis for this work. Soil maps of that survey are on 1:100 000 scale with 1:20 000 soil maps on uncorrected aerial mosaics for Upolu Island. A detailed soil survey (1:20 000) of the Asau Block in Savai'i (Cowie 1979) was incorporated in new 1:50 000 soil maps. Chemical analyses of soils described in the two surveys were used as an initial guide for soil classification. Soil analyses and classifications according to Soil Taxonomy for some soils were also available from Schroth, 1971, Morrison *et al.* 1986, and University of the South Pacific, 1986, although in some cases the wrong soil series names were used in the latter two publications.

3.2.2 Aerial photo interpretation

Aerial photographs at scale 1:20 000 (1981) with a partial cover of northern Upolu at 1:13 000 (1980) and a cover of aerial photographs at 1:50 000 (1987) were used for interpretation.

Wright's survey of Upolu on aerial mosaics (1:20 000) was checked using the above aerial photos and a full aerial photo interpretation was done of Savai'i. The interpretations inserted more topographic detail on Savai'i and corrected some of Wright's work on Upolu.

3.2.3 Field work

About 2 months (4 man months) were spent in the field during which almost all soil series were described several times in different locations (190 soil profile descriptions) and 33 key soil profiles were sampled (101 samples). The samples were sent to the Division of Land and Soil Science, Lower Hutt, for specific analyses needed for classification according to Soil Taxonomy.

Samoan counterparts were given on-the-job training and were involved with all field work thus ensuring a smooth operation and adding valuable manpower to the project.

3.2.4 Compilation of Soil Maps

Information collected from aerial photo interpretation and field work was plotted on 1:20 000 topographical maps with contours using Wright's survey as a base. The resulting soil maps are therefore a combination of Wright's survey, topographic information, photo interpretation and field work. The soil maps were then digitised and reduced to 1:50 000.

3.3 SOIL ENVIRONMENT OF WESTERN SAMOA

3.3.1 Parent Materials

Parent materials of Western Samoan soils consist of olivine basalt, and andesite, lithic and lithic vitric tuff, alluvium and colluvium, coral sand, basaltic sand, organic material and estuarine deposits. Most of the soils are formed from basaltic volcanic flows differing mainly in age and kind of deposit (pahoehoe, aa or scoria). Volcanic ash associated with past eruptions forms part of the parent materials of many soils.

The influence of basalts on landscape and soils is expressed in Table 3.1. (after Wright 1963). They are listed in order of age.

Table 3.1 *Geological Formations and Their Relationship to Landscape Dissection, Soil Depth, Soil Surface and Soil Texture*

Geological Formation	Dissection of landscape	Average depth of soil	Soil surface	Soil texture
Fagaloa Volcanics	strong	>100 cm	few to many boulders	clay, silty clay
Salani Volcanics	moderate	50-100 cm	few to many stones and boulders	clay, silty clay
Mulifanua and Lefaga Volcanics	slight	15-50 cm	boulders and stones	clay, silty clay silty clay loam
Puapua Volcanics	v. slight	15-50 cm	boulders, stones and rock	silty clay loam silt loam silty clay
Aopo Volcanics	v. slight	0-25 cm	rock, boulders and stones	sandy gravels silt loam
Vini Tuffs	moderate	>100 cm	few stones	clay, silty clay loam

The Fagaloa Volcanics occur in north-eastern and south-western parts of Upolu and in north-eastern parts of Savai'i. The areas are deeply dissected and boulders and stones occur chiefly on steep and very steep slopes and on the bases of the slopes. Soils are formed from pahoehoe, aa, scoria and dykes of basalt.
Salani Volcanics occur throughout both islands chiefly on upper foothills and uplands. Scoria cones are numerous, although most soils are formed from pahoehoe, aa, or a mixture of these.

Mulifanua, Lefaga and Puapua Volcanics form the parent materials of the greater part of Upolu and Savai'i. Soils are formed from aa, or aa and pahoehoe basalt, or scoria.

Aopo Volcanics are restricted to relatively recent flows and their youthfulness is expressed in flattish, extremely stony and bouldery surfaces with large areas of pahoehoe basalt at or near the surface.

Vini Volcanics occurs on offshore islands, east of Upolu and in southeastern Savai'i. The tuffs have weathered more rapidly than the olivine basalt and very few stones occur in the deep soil.

Colluvium occurs on the lower parts of hilly and steepland particularly on Upolu. The material includes many stones and boulders which moved downslope.

Alluvium deposited by the main rivers is not extensive in Samoa, but forms the parent material of the most versatile soils.

Coral sand strips along the coastline lie in front of swamps and depressions in which organic deposits overlie coral or basaltic sands. Locally they are intersected by estuarine deposits under tidal influence.

Shallow upland peats occur in a few small areas in Upolu and in central-eastern Savai'i.

3.3.2 Climate

Western Samoa has a warm humid climate marked by a distinct wet season (November-April) and dry season (May-October).

Average annual rainfall varies from 2500 mm on the western side of both islands and in northern and part of eastern Savai'i, to about 6000 mm in upland country. During the wet season, this varies from about 1500 in the drier parts of the islands, to 4000 mm in the uplands and during the dry season it varies from 750 mm to about 2000 mm.

There is a strong relationship between altitude and precipitation. From cross-island transect records between 1973 and 1976, Hoops (1976) found linear increases of 260 mm per annum per 100 m increase in altitude for the north slope, and 360 mm per 100 m for the south slope.

The predominant easterly and south-easterly trade winds invoke the high rainfall in eastern Upolu and a rainshadow effect on western Upolu, eastern, northern and western Savai'i.

In terms of Soil Taxonomy the broad division of udic and perudic moisture regimes are used for a major division of the soils (Appendices 2 and 3). A udic moisture regime implies that in most years the soil moisture control section is not dry in any part for as long as 90 days (cumulative). Dry periods can therefore occur during the year. In Western Samoa areas with a udic moisture regime occur chiefly on the western and northwestern sides of Upolu and Savai'i and the northern and eastern parts of Savai'i.

A perudic moisture regime implies that the soil moisture control section is moist throughout the year.

An aquic moisture regime occurs in wet or swampy areas where the soil is saturated by groundwater or water of the capillary fungi, for long periods (reducing conditions). In tidal marshes the moisture regime is called peraquic.

Mean monthly temperature at all elevations vary little during the year with values ranging from 25.5 to 26.5°C at sea level and 21 to 22°C in the mountains. The diurnal range is much larger, varying between 6.0°C and 8.9°C. The temperature lapse rate has been estimated at 0.66°C per 100 m (Scattarella 1977). The warmest months are February through March, the coolest July and August, with seasonal variations being similar at all altitudes. The all time maximum was 35°C recorded at Faleolo, the minimum of 11.1°C recorded at Afiamalu. The 'Fohn' effect of the prevailing south-easterly trade winds causes slightly higher temperatures in the north-west parts of the islands (Scattarella 1977).

The soil temperature regimes (Appendix 3) from Soil Taxonomy classify soil temperatures at 50 cm depth as follows: hyperthermic, 22°C or higher with a difference of 5°C or more between seasons, and isohypthermic, 22°C or higher with a difference of less than 5°C between seasons.

3.3.3 Physiography

The landscape of Western Samoa can be broadly divided into:

1. Coastlands, valley floors and their margins

2. Lowlands and foothills

3. Uplands

Further subdivision can be made according to the dissection of the landscape and parent materials of the soils (Appendix 1).

1. The coastlands, valley floors and their margins.

   The coastland forms a complex fringe around the islands. Flat coral beaches are interrupted by estuarine inlets, basalt flows and alluvial deposits from rivers and colluvial deposits and fans from foothills. Behind the beaches swampy depressions, filled with colluvium or alluvium, often have flat peaty surfaces. The main rivers carried material from uplands and foothills to be deposited on flat alluvial terraces. Further inland, these rivers are deeply incised with much smaller alluvial flats often covered with colluvial fans.

2. The lowlands and foothills stretch from the coast into the uplands. Extensive lava flows of different ages run from the uplands towards the coast and are dissected by incised rivers. The lower part of this landscape appears to be flat to rolling land becoming strongly rolling and hilly towards the uplands. Numerous scoria cones interrupt the landscape. The older volcanics (Fagaloa Volcanics) which are extensive east of Apia and in southwestern Upolu are deeply dissected and steep and very steep country extends towards the coast.

3. The uplands (above about 2000 feet) consist of flat to rolling and some hilly land interspersed with numerous scoria cones and volcanoes. Flat upland depressions occur in the eastern part of Savai'i and in few small areas in Upolu.

3.4 SOILS

The map legend and Appendix 1 have the soils arranged physiographically. Appendix 1 presents the physiographic legend with natural drainage classes (Taylor and Pohlen 1979) and correlation of map symbols with those of Wright (1963). Appendix 2 presents a key for rapid identification of the soil series. The soils have been classified according to Soil Taxonomy (Appendix 3), the FAO classification (Appendix 4) and compared with the soils of American Samoa (Appendix 5).

3.4.1 Soils of Western Samoa arranged according to physiography

The legend on the soil maps and Appendix 1 lists the soils under physiographic units. The soil types listed correspond to the landscape units established by Wright (1963) so that close correlation with his survey could be maintained.

Soil map units are represented by one or more delineations on the soil maps bearing a unique symbol. The legend lists the symbols used to designate map units under physiographic units. Map units are identified by:

1. A soil type, specified by the geographic name of the soil series of which it is part, with or without additional terms denoting soil texture stoniness, depth, etc., that distinguish the particular soil type from others in the soil series.

2. A phase of a soil type (e.g., 19a Falealupo very bouldery silty clay loam, peaty phase), which is a subdivision of the soil type.

3. A hill or steepland soil, specified either by name of the dominant soil series on neighbouring rolling land or by the model soil series on the steep slopes. Hill and steepland slopes are complex map units with considerable spatial variability in component soil classes.

The geographic name of the soil type is followed by the soil texture of the upper part of the soil. Gravels (up to 8 cm diameter), stones (8-25 cm diameter) and boulders (over 25 cm diameter) occur in many soils and have been used to distinguish soil types. Gravelly, stony and bouldery soil types have up to 35 percent by volume, and very gravelly very stony and very bouldery more than 35 percent by volume of that rock size in the soil profile.

Appendix 2 presents a key for identification of the soils at series level.

The soil series is a grouping of soil types with similar model profiles, temperature and moisture regimes and the same or very similar parent materials. The key identifies the soils firstly at moisture and temperature regimes and then places the soil series in the landscape. Further identifiers are physiography, location, stoniness, and soil profile properties.

3.4.2 Correlation of Soils with Wright (1963)

Wright divided the soils of Western Samoa in four broad topographical groups (lowland - foothill region - upland region - highland region). In comparison, this survey separates the coastal region, foothill region and upland region. The survey of Wright then uses a complex system of major and minor soil suites, further subdivided into soil series and mapping units. In this survey further subdivisions were made according to topography and parent material differences. Many of Wright's soil series and mapping units were retained in this survey. Wright recognised 90 series with a total of 242 mapping units. This has now been simplified to 86 soil series with 197 mapping units. In Appendix 1 Wright's map symbols are listed behind the soil types of the physiographic legend.

Similar climatological subdivisions were used in both surveys: Wright's uplands and highlands regions are approximately isothermic and his lowland and foothill regions isohyperthermic. The weak to strong dry season of Wright correlates with a udic moisture regime and the very weak dry season to no dry season correlates with the perudic moisture regime of this survey.

3.4.3 Soil Taxonomy

The soils have been classified according to Soil Taxonomy using existing data (Schroth, 1971; University of the South Pacific, 1986, and Morrison *et al.* 1986), and additional data from samples taken during this survey. The locations of the new sampling sites are indicated on the soil maps.

Wright described the soils of Western Samoa in terms of soil series and soil types and these soil classes were used to define map units. The soil series, however, were not well defined in terms of soil properties. In the light of the current work and other studies the soil series can in most cases be confidently placed in a single subgroup of Soil Taxonomy, except where the series includes both deep and shallow soils over rock. In these cases, for example the Upolu series, the series is correlated with a typic or other subgroup and with the lithic subgroup.

Correlation of soil series with soil families is much less certain, mainly because many of the series have a wider range of particle-size classes than allowed in a single family.

The latest available taxonomic classification was used to classify the soils (USDA Staff, 1988 and Leamy *et al.* 1988) and the Taxonomic legend is arranged according to the key of Soil Taxonomy:

Histosols

Few Tropofibrists occur on lowlands (Hydric subgroups) and in uplands (Fluvaquentic subgroups). Other wet areas classify as Tropaquepts or Aquic Tropopsamments.

Andisols

The major part of the Savai'i uplands are dark coloured, humus rich Fulvudands extending in some areas to upper foothills. Some of these uplands are Hydric Hapludands. Hapludands occur on the foothills of both islands. The extent of Andisols in Western Samoa expresses the amount of volcanic ash present in the soils.

Oxisols

Most soils are too stony and bouldery to qualify as Oxisols. Those that do qualify are derived from the Lefaga Volcanics and are confined to stable ridges and plateaux in the strongly dissected landscape. Problems arise where stony subgroups occur in the one series and for example Fagaga silty clay loam is an Anionic Acroperox and Fagaga stony or very stony silty clay loam Andic Humitropepts. Further soil work would split these series up on the basis of classification.

Mollisols

There are few Mollisols in Western Samoa since generally the soils are too strongly leached to qualify. Some soils derived from alluvial deposits (Apia and Sauniatu series) and some soil occurring on shallow recent lava flows make up the bulk of the Mollisols.

Inceptisols

These are the most widely represented in Western Samoa. Humitropepts are abundant commonly with oxic and andic subgroups. The wide extent of Humitropepts and Dystropepts reflects the strongly leached status of the soils. With the exception of some Eutropepts on different parent materials (calcareous tuffs and scoria), many of the oxic subgroups would qualify for Oxisols if they had fewer stones.

Entisols

These are restricted to coastal areas and, in the case of Matavanu series, to recent lava flows. The coastal soils are tidal (Sulfaquents) or coral sand deposits (Tropopsamments).

Soil families included in the series

The family described on the map legend with each soil series refer to the main soil within the series. Additional families are listed in some cases where the necessary data were available. There are a considerable number of families not listed in the legend mainly because particle size and mineralogical analyses were not carried out, and to simplify the legend. Appendix 3 presents the classification according to Soil Taxonomy at type level with an indication of the kind of data from which the classification for each soil type were derived.

3.3.4 FAO Classification

The soils are classified according to the FAO classification (FAO 1986) and listed in Appendix 4. Although the FAO classification uses similar diagnostic criteria as Soil Taxonomy, there are fewer subgroups. Therefore many of the soils key out the same. The soils are listed according to the FAO key. In broad terms FAO and Soil Taxonomy orders compare as follows:

FAO	SOIL TAXONOMY
Histosol	Histosols
Leptosol	Lithic subgroups of Mollisols, Inceptisols and Entisols
Fluvisol	Entisols, Mollisols
Gleysol	Aquic subgroups of Entisols, Tropaquepts
Andosol	Andisols
Ferralsol	Oxisols
Cambisol	Inceptisols (Humitropepts and Dystropepts)

3.4.5 Soil of Western Samoa compared with those of American Samoa

American Samoa was briefly visited by Wright (1963) who compared soils of the two countries. A more detailed survey of American Samoa was carried out by Nakamura (USDA 1984) who also classified the soils according to Soil Taxonomy.

Soil Taxonomy is a useful aid in comparing soils of different countries, but during the survey of American Samoa the newer classification sections of Soil Taxonomy were not available. Therefore the older versions of Soil Taxonomy have been added in brackets to the classifications of Western Samoan soils (Appendix 5). However, some specific analyses needed for older versions of Soil Taxonomy were not carried out and a direct comparison was therefore not possible in a few cases.

Parent materials of American Samoan soils are basic rock (mainly basalt) and small amounts of andesite, similar to the Fagaloa Volcanics of Western Samoa. Other parent materials are volcanic ash and cinders, colluvium, alluvium and minor areas of organic material and coral sand.

American Samoa has an isohyperthermic temperature regime whereas Western Samoa extends to isothermic in the uplands. Similarly, the rainfall range of Western Samoa is greater and there is no udic moisture regime in American Samoa. The soils of both countries have considerable amounts of organic matter accompanied by dark soil colours, but with the strong leaching environment in Western Samoa, many of the soils are Inceptisols (Humitropepts and Dystropepts), compared with weakly leached Mollisols in American Samoa.

Comparable soils of both countries are listed in Appendix 5.

SECTION 4. LAND CAPABILITY

4.1 INTRODUCTION

The logical conclusion of any soil survey is the interpretation of the soils for the best land use. Optimum land use is not always possible because of land owner preference, economic considerations and land ownership, but it is useful to show the capability of the land and indicate which soils are best suited for which crops and which soils should not be used for agriculture or forestry.

The land capability maps are derived from the soil maps and are accompanied by a simple legend. In this section this legend is further discussed and extended to crop recommendations and land improvement measures to achieve optimum usage of the soils.

4.2 METHODS

The major land characteristics such as drainage, droughtiness, erosion risk, natural nutrient availability, surface rockiness, rooting volume, salt spray salinity, slope, surface stoniness, pH, particle size class and elevation were first classified for each soil and the information stored in the GIS system.

Land capability classes were then constructed from this data base and firstly divided into few - moderate - severe and unsuitable classes for agricultural and forestry uses.

Subclasses were then constructed using land characteristics that are not easily changed such as climate, stoniness, slope, natural drainage, erosion potential, soil depth, and salinity.

The land capability legend was then further extended (Appendix 6) to include crop recommendations for each class. Information was gathered from data base material gathered from literature (Appendix 7), field observations, Wright (1963) and comments from Samoan agronomic counterparts.

4.3 RESULTS

The results of the land capability classification are listed in Appendix 6. Class 1 are the most versatile soils of Western Samoa and include recent soils that occur along the major rivers and around Apia.

The soils included in Class 1a are under utilised at present and with artificial drainage corrections and protection against flooding, these soils represent the greatest potential for Western Samoa. Different soils have different nutrient requirements and only the general nutrient requirements are listed. Crop specific nutrient requirements are listed in Appendix 7. Cocoa has been left out in Class 1b since the environment is too wet for this cash crop. There are many areas without moisture deficit in Western Samoa where cocoa is severely affected by fungal diseases. Block shading is essential if some of the crops listed for Class 1 are to be successful.

Class 2 includes land with moderate limitations to agriculture and few limitations to forestry. Soils are too stony, their moisture deficit too high without readily available irrigation water or have other restrictions for intensive agriculture.

Class 2a includes soils that cannot be ploughed because of stoniness and are therefore better used for tree or bush type crops. The environment is too wet for cocoa.

Class 2b would need irrigation for some crops. Stones and boulders prevent ploughing except for Vini clay (50).

Class 2c - Contour planting would be a good practice to prevent erosion. Pasture is only recommended on hill soils with few stones or boulders at the surface and citrus would probably grow better at higher elevations.

Class 2d are the somewhat drier hill soils where cocoa would be free of diseases. Sataua hill soils (24H) would be best in forestry because of the very bouldery or stony nature of the soils.

Class 2e are soils which probably would be uneconomic to drain for agricultural production. Salt spray affects the Mutiatele series (4 and 4a) and only salt-tolerant species could be grown such as guava, coconut, pandanus and pulaka.

Class 2f contains the upland soils under very high annual rainfall. Citrus orchards would be an option but the soils are probably best in pasture.

Class 3 contain the soils with severe limitations to agriculture and moderate limitations to forestry. The improvements are less specific as in many cases further improvements are uneconomical and it would be more realistic to adapt land use to the limitations.

Class 3a includes the coastal sands well suited to coconut, pandanus and breadfruit trees, mulching is beneficial for these soils.

Class 3b contains a wide range of hill soils under high annual rainfall. Erosion potential is moderate to severe, but with contour planting some crops can be grown. Commercial forestry is an option for these soils if adequate erosion control measures are taken.

Class 3c is similar to Class 3b, but with a seasonal moisture deficit. Similar land use is recommended, but ta'amu instead of taro crops on slopes under 25 degrees.

Class 3d includes soils with restricted root volume with pahoehoe lava close to the surface. This depth can vary within the soil series and it therefore does not completely exclude deep-rooting crops such as ta'amu,

Class 3e contains the upland soils, where particularly on Savai'i access is difficult at present. The soils are fragile and have a potential for severe erosion if brought into cultivation. Extremely stony soils are included in this class.

Class 3f Peats and clays overlie pahoehoe lava at relatively shallow depths. Such soils are best suited for pastoral use if drained. The economics of drainage are doubtful at present.

Class 4 contains soils unsuitable for agriculture or forestry. Most of the steepland soils are listed in Class 4a and these soils would erode severely if brought under cultivation. There are already clear examples in Western Samoa where severe erosion is active. Therefore conservation forestry and creating reserves for recreation are the best options.

Other groups in Class 4 are extremely shallow soils where pahoehoe lava is at the surface (Class 4b) and very wet or saline soils that are uneconomic to improve.

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SECTION 5: EVALUATION OF ALTERNATIVE LAND USE ON DIFFERENT LAND CAPABILITY UNITS

5.1 TYPES OF INFORMATION

Various types of information may be sought by decision makers who make choices about the use of the land resources of a nation. Such decision makers include owners, or traditional custodians of the land, and politicians who set policy or decide on public expenditure involving land use. The advisors for such decision makers seek to provide the information that will aid good decisions. These advisors are extension officers in the case of providing information to land owners and custodians. In the case of informing political decision makers, the advisors can be generally termed land use planners.

The types of information provided can include:

- i technical information about production methods;
- ii economic information that measures the net benefit or net return of different land uses;
- iii social information concerning impacts on social relationships in families and communities from the adoption of new land patterns;
- iv environmental information concerning impacts on resources such as land, water, and natural forest, mangrove and reef ecosystems that occur from the adoption of new land use patterns.

The impacts in iii and iv often affect people other than those who make the decisions and receive the benefits from the adoption of the new land use pattern.

5.2 ECONOMIC TOOLS FOR ASSESSMENT

Various economic tools are available for assessing the net benefit of alternative land uses. Which tool is the most suitable will depend on which group of decision makers is being advised.

Appendix 8 discusses in more detail the economic assessment of crop and forestry enterprises (A8.1), cattle production (A8.2), and watershed protection (A8.3).

5.2.1 Farmer Level Decisions

For extension officers advising farmers two options can be used. For one farmer with a particular project, a budget can be prepared showing the expected additional costs and benefits for that proposal on a specific site and with that farmers level of management.

Such an approach, however, involves a lot of time and the information benefits only one farmer. Another economic tool that can be applied by many farmers is a gross margin. A gross margin gives the return to a particular land use, for example, taro production, in tala per acre. A gross margin considers the returns and the variable costs of the enterprise. It is used to allow the farmer to choose between alternative enterprises which can utilise a farmer's fixed resources of land, labour and capital.

5.2.2 Policy, Programme and Project Decisions

To decide which economic tool is suited to advising political decision makers, we should recall the types of decisions to be made. Land use planners are providing information, to guide decisions by politicians, on land use policy and on public expenditure for programmes and projects undertaken by government departments.

Land use policy deals with the framework of legislation and its objectives, plus regulations and incentives that guide or control the actions of individual land users. Policy is generally based on broader concerns than the economic returns of a particular land use. It is more likely to be based on information covering the social and environmental impacts of alternative land use. For example government may wish to have a policy that ensures sustainable land use, so that the soil resource is available to future as well as present generations of users. Thus government is acting to constrain present users in a way that avoids the present use imposing costs on others.

Land use programmes and projects of government include providing services in support of particular land uses, and investing in a land use proposal for a particular area. Programmes and projects take place within the policy framework, promoting economically sound land use for particular soil and land capability classes. Economic information needs to be relevant to the land capability class. The costs and returns of alternative land uses in this case also needs to include their different fixed cost requirements. It is necessary to present results for long term and short term land use in a way that their comparison is valid.

A Modified Gross Margin for Land Use Planning

For these reasons the gross margin tool is extended to consider fixed costs relevant to the land use enterprise. It is also used as a multi- period gross margin. The results are obtained by calculating a present value for the costs and benefits. The present value takes account of the time value of money, and is obtained by discounting the net revenue stream.

The programme MULBUD was used to produce such gross margins. It has the advantage of producing tables which show clearly the assumptions used. Costs and prices can be readily updated as can the physical quantities of labour and materials used, or outputs produced. The discounted results can be checked at different discount rates. The sensitivity of the result to variations in the expected level of output is provided. This range in the results can be related to the land capability unit on which the enterprise is to be conducted.

The sum of net present value (SNPV) result per acre can be compared across the range of different land use options. Inappropriate options will already have been excluded by the policy framework on social and environmental grounds.

Economic analysis: The SNPV used for planning purposes should be from the *economic analysis*. This gives the return to the nation. It takes out the effect of subsidies and taxes and puts a value on labour use even if this is unpaid family labour.

Financial analysis: The SNPV used by individual producers and extension officers should be from the financial analysis, which considers costs and returns only as they apply directly to the producer. This group are also frequently interested in the average value for net revenue per labour day for the enterprise as this can be related to the average daily wage.

A summary of the enterprise results for the economic and financial analyses is given in Table 5.1.

Table 5.1 *Summary of Enterprise Analysis (yield ranges are presented to indicate the effect of land capability). Values are given per acre because Western Samoa uses non-metric units of measure.*

	Economic Analysis				Financial Analysis	
Enterprise	**SNPV 10% $**	**IRR %**	**Effect on SNPV for + 20% Yield**	**-20% Yield**	**SNPV 10% $**	**Net Rev/Day $**
Local Tall Coconut	-80	9.0	300	-461	1266	11
Hybrid Coconut	680	12.4	2344	-984	6704	14
Smallholder Cocoa	70	10.9	402	-262	1020	17
Amelonado Cocoa	-496	6.6	312	-1325	2538	15
Smallholder Coffee	2595	35.6	3490	1698	3764	28
Plantation Coffee	2889	20.4	5433	344	9412	19
Export Banana	-144	1.9	1685	-1974	6959	42
Local Market Banana	3102	>100	4062	2142	4224	45
Passionfruit	-531	5.8	1526	-2589	4800	21
Mango	920	16.5	1721	118	2961	31
Taro	2666	>100	3560	1773	3189	80
Tomato	3961	>100	5399	2523	5970	99
Cucumber	1164	>100	1560	767	1533	121
Chinese Cabbage	-84	6.0	313	-481	551	104
Forestry (Eucalyptus deglupta)	411	16.9	569	254	222	
Forestry (Mahogany)	65	10.5	193	-62	22	
Agroforestry	14589	>100	18486	10694	15943	74
Beef Breeding						
under coconut						
good land	9	10.6				174
limited land	-24	8.6				173
open pasture						
good land	40	11.3				175
limited land	0	10.0				174
developed from forest	-132	4.1				173
Beef Fattening under Coconut						
good land, with water	362	24.2				198
good land, no water	165	18.1				123
limited land, with water	213	21.5				197
limited land, no water	87	15.8				122

Yield and Land Capability Relationship

At this point the relationship between land capability and yields in Western Samoa is not well established. As information is obtained on this relationship, the sensitivity range used in the MULBUD programme can be adjusted to reflect the yield differences expected.

Data that might provide the relationship were examined. Coconut yields over a period of 5 years at different sites were available in summary form but the management applied at each site differed so that yield differences included more than just the site differences. Cocoa demonstration plots at a number of different sites have been in place for nearly 8 years. Data by year was not available. This data, however, would be invaluable as the management of sites was reasonably uniform. It is recommended this information be brought together.

Forestry permanent sampling plot data was reviewed against the latest timber production models available to the Forestry Division. The timber production models are by site index so that the expected site index of different sampling plot locations could be gauged. The site index classification should be related to the land capability rating when it is produced. It is noted for example that Revilla (1988) expected, from his models that at 15 years for *Eucalyptus deglupta*, that there would be a range of 53 m^3 per ha to 284 m^3 per ha for site indexes of 25 (poor) to 40 (very good).

Results from the gross margin analysis

The results are given in Table 5.1 for economic and financial analyses.

The standard discount rate used to obtain the sum of net present value (SNVP) was 10 percent. Another measure to compare enterprises is the internal rate of return. (These measures are discussed further under cost benefit analysis results.) The effect of yield increase or decrease on the SNVP completes the economic results. The financial results include SNVP. This result does not cost family labour, and so for years when full yield is reached average net revenue per day is calculated from the annual net revenue.

Coconuts

The returns from the local tall are less than the 10 percent standard, while hybrid coconuts yield a good result at $680 per acre. The hybrid coconuts, however, show a big range in the results for yield changes because of the higher levels of inputs used.

Cocoa

The high input, high yielding Amelonado cocoa has shown a poor result due to poor price forecasts for world cocoa price. In these circumstances, lower input cocoa under the smallholder model gives a better economic result. The input-yield relationships giving this result need further research.

Coffee

With better price expectations, coffee is showing a very good economic result. The labour input for harvesting is high, and this needs good management.

Banana

Low input banana production achieves a good result for sales on the local market. In this case price fluctuations can give the range in SNPVs shown in the table from yield variation. Export banana production, with high input costs and prices held down by a competitive export market, give a poor result. While heavy subsidies make this attractive to farmers the return to the nation is poor.

Processed fruit

Mango and passionfruit are processed for export as pulp and sold locally as juice. Passionfruit faces strong price competition and with significant production costs is giving a poor result. Mango looks promising, but this is based on tentative production estimates. There is little experience with mango planted in plantations.

Taro and vegetables

These short-term crops all gave strong economic results except for chinese cabbage. Production levels are based on growing in suitable soils and climatic zones for these crops.

Forestry

Plantation forestry is showing reasonable economic returns in comparison with coconut and cattle breeding. An agroforestry enterprise is examined further in the cost benefit analysis case study as an alternative land use to reduce pressure for land clearance. Its dramatic return reflects the fact that it achieves sustained taro production.

Beef breeding

These results reflect the establishment costs for this option and in the case of development from forest is uneconomic. Returns are similar to coconut production.

Beef fattening

Based on current prices for young stock a high rate of return can be expected with a significant increase in the return where water is available.

Assessing Programmes and Projects: Cost Benefit Analysis

Planning activities on the basis of the modified gross margin data above may have lead to proposals to encourage and support a particular range of enterprises for given land classes in a particular district. The project proposal requires evaluation and information presented for political decision. Cost benefit analysis is a useful tool for collecting, analysing and presenting the information.

To make a decision about whether to implement a project, decision makers generally information about the impacts of that project. What will the project cost, what benefits will it produce, when will the benefits occur, who will receive the benefits, what risks are there to achieving the benefits, and are there social and environmental impacts that cannot be counted together with the other costs and benefits because they are difficult to value in monetary terms?

It is useful to know what criteria the decision maker will use for judging the project before the proposal is put together and assessed, so that the information can be put together as required. It is also useful to have a consistent method for assessment so that the results can be compared between alternative projects which are candidates for funding. Cost benefit analysis (CBA) is a standard procedure for assessing the costs, risks and benefits of projects and programmes, that is widely used by governments, aid agencies and financial institutions to help judge their suitability for funding.

A Standard Methodology

From Which Point of View is the CBA Undertaken?

A financial CBA considers the costs an benefits to an individual within the project. The individual may be a farmer planting a crop under the project, an institution providing services to the farmer as part of the project, or a processing plant set up under the project to purchase the farmer's crop and process it for sale.

A economic CBA considers the costs and benefits to the country from undertaking the project. It will therefore cover the costs and benefits to all the participants as well as costs and benefits that result from impacts outside the project.

We shall consider the standard methodology for an economic or national CBA, though many of the general principles can be applied to undertaking a financial CBA for a individual participant.
Decision makers are likely to want to know, that the operations of individual participants within the project are viable, as indicated by a financial CBA. This is an important criteria for financial institutions funding those participants.

Decision makers are also concerned with the overall impacts of the project as indicated by an economic CBA. This applies particularly to aid agencies and governments.

Economic or National Cost Benefit Analysis

Assessment of Costs

1. The costs **with** the project should be compared to the costs **without** the project. This may not be the same as the costs before the project compared to those after the project starts.

2. The actual capital and maintenance costs are shown in the year in which they occur. We do not use a capital allowance such as depreciation to represent the capital cost. Each year in the analysis represents a point in time. For example, year 0 is the beginning of the first year, year 1 is the end of the first year and the beginning of the second year, and so on. Capital expenditure is assumed to occur at the beginning of the year in which it actually occurs, while maintenance expenditure and revenues are assumed to occur at the end of the year in which the actually occur.

3. The costs to be used are the actual **resource** costs to the nation. This does not include costs that are only transfers within the nation that do not represent a use of resources. Examples of these transfer costs which are excluded from the analyses are taxes, interest payments within the country and land purchase costs. They are, however, financial costs to be used in the financial CBA for individual participants.

4. The costs used should be the expected costs of the project. If from experience actual costs are say 20 percent more than those estimated, then a 20 percent contingency cost should be included. However this should be for physical contingencies only. For the CBA, real cost and prices are used and inflation is excluded. Real costs and prices mean that they are assessed at the one point in time, usually at the beginning of the project. Note, however, that for funding of a project, a price contingency or inflation allowance will be needed for expenditures in later years.

Assessment of Benefits

1. We estimate the benefits expected **with** the project compared to those **without** the project.

2. The prices used to value the outputs of the project are in the same tala as the tala used to value or cost the inputs. That is, they are assessed in tala at one point in time, usually at the beginning of the project. Note however that the prices, in those **real** terms, are the projected prices when the project's outputs occur. For agricultural products where medium term trends occur due to changes in the supply and demand situation, the price predicted by the trend should be used.

3. The outputs estimated from the project should be a realistic assessment of what is actually expected to be achieved by the project participants. The estimate of outputs should therefore allow for risks involved such as droughts, hurricanes and pest and disease effects. The expected outputs should be based on a consideration of likely farmer response and not on what researchers think could or should be achieved.

4. It is necessary to consider the other impacts or unpriced costs and benefits that result from the project. More attention is given to this aspect later.

Analysis

1. A standard discount rate should be used to bring all project costs and benefits to their present value. The discount rate used should be that set by the funding agency. Governments may set a discount rate at the cost of obtaining funds, for example equal to the interest rates paid on Government loans. Alternatively Government may set a discount rate at the level it sees that society values providing for the future.

2. Note that long term projects are disadvantaged by use of a high discount rate. For example forestry production and tree crops generally show a lower rate of return compared with short term crops and industrial projects.

3. The standard discount rate used in CBA is sometimes used as the rate of return which must be achieved for the project to be approved for funding.

Results

1. Results of a CBA can be presented in different ways. The **Net Present Value** is the present value of benefits less the present value of costs at the standard discount rate. It is the preferred measure for decision making.

2. The **Internal Rate of Return** is the discount rate at which the present value of the benefits equals the present value of the costs. It can be readily understood by decision makers in comparison to interest rates. However selection of projects based on their internal rate of return unduly favours short term projects.

3. **Sensitivity analysis** checks the effects on the results of changes in important assumptions. For example, what happens to the results if there is a decrease in expected price or an increase in budgeted costs. This is one way of helping decision makers understand the risks associated with the project.

Unpriced Costs and Benefits

Unpriced costs and benefits usually relate to impacts of the project on environmental resources which belong to the nation or the community and not to individuals or families. Examples are rivers, forests, birds, mangroves and fish. They are called **common property resources**.

Often there are traditional systems for regulating or controlling the use of common property resources, in the interests of the community or traditional unit of society. For example, there may be periods when fishing or sea food gathering is prohibited by the village fono, or where controls are set on who can cut down bush for planting.

Traditional controls should not be overlooked by governments wanting to encourage development, or wishing to use restrictions on individual activities for the good of the nation and its future.

A case study is presented in the Appendices. The assessment follows a standard methodology, allowing comparison between projects competing for government funding. The method requires the analyst to systematically consider and evaluate the impacts of the project. Assumptions need to be made explicit, particularly concerning the rate of adoption of the promoted land use as a result of the project's activities. The risks also need to be taken into account in the expected results generated. Even where valuation of the impacts is not feasible or appropriate, description of the effects in some quantitative way assists decision makers.

5.3 CONCLUSIONS AND RECOMMENDATIONS

5.3.1 Information

Agreement between decision makers and advisors is needed about the information required for decisions on land use policy, programmes and projects. Both groups need to be fully familiar with the new information available from the land resource survey and its geographic information system.

Research and farm survey work is needed to provide good information for different production systems (high and low input). This work should cove different land capability classes. Crop requirement data provided by this study can be used to select the most promising enterprises for further research on the different land capability classes.

Social and environmental effects of land use is the information needed to develop land use policy. Land use policy is the framework within which economic analysis of alternative programmes and projects can take place. A policy of sustainable land use that does not disadvantage future generations is recommended.

Recommendations

That DAFF research and farm survey programmes be organised to provide information on enterprise yields from different land capability units.

That farm survey data be obtained for low input enterprise options of significant crops.

That DAFF promote a proposal for discussion and adoption by Government for land use policy to be based on sustainable practices and enterprises an taking land capability into account.

5.3.2 Economic Assessment

Economic assessment should suit the type of decision.

Advice to farmers on enterprises they may wish to choose from, can best be provided using financial gross margins. Gross margins based on land capability units need to be developed from the research suggested above. Extension officers need to have a set of gross margins for enterprises suited to their district. The enterprises should include crop, livestock and forestry options. Returns per labour day are a valuable and easily understood criterion for farmer decisions. However, the present value per acre is important where land is the limiting factor.

Advice for political decisions should be based on economic gross margins and economic cost benefit analysis. These measures will help evaluate a project or programme which Government is considering.

"Mulbud" is a useful package for presenting enterprise gross margins. It allows input, output and price data to be easily revised so that gross margins can be kept up to date. It is recommended that DAFF economists programme time to do an annual update of gross margins using new price projections and current costs. Mulbud output files can be accessed by a word processing package to give the desired presentation in a gross margin manual.

Recommendations

That each extension officer be provided with a set of financial gross margins for crop, livestock and forestry enterprises suited to that district.

That DAFF economists programme for an annual update of gross margins based on current price projections and costs.

5.3.3 Analysis Results

Good economic returns have been indicated by many of the low input crop options. These results are likely to be dependent on reasonable natural fertility but investigation and extension of low input options deserves support.

Conservation or protection options for land use are not suited to gross margin analysis. Land use policy may define a number of land capability units to be restricted to protection uses on the basis of physical use limitations. Alternatively programmes may be developed for a village's land area or a watershed area where land use options including protection can be evaluated using a cost benefit analysis approach. Standard cost benefit methodology is recommended as a way of ensuring that all of the impacts and the assumptions are made clear.

Recommendations

That DAFF promote the use of a cost benefit analysis framework for the presentation of proposals for Government approval and funding.

That DAFF use a standard cost benefit analysis approach to the assessment of important options for its programmes and projects.

SECTION 6: CARTOGRAPHY/GEOGRAPHIC INFORMATION SYSTEM (GIS)

6.1 INTRODUCTION

6.1.1. Original Cartography Plan

The original requirement was for six topographically-based soil, six land use and six land capability maps at 1:50 000 scale to be hand-draughted by local counterparts in Western Samoa under supervision of the Project Cartographer. The compiling at 1:20 000, data collection, work scheduling and production was a very ambitious task in the time-frame and on start-up it was realised that the skill levels of available counterparts fell short of requirements. A request to modify the proposal methodology to produce the maps as a computer/plotter product via the GIS computers, prior to GIS startup, was agreed by ADB.

6.1.2 Revised Mapping Plan using GIS computers

GIS is essentially a digital method of spatial, cartographic expression for which the same rules of compilation, verification, accuracy, etc. apply.

6.2 SET-UP

6.2.1 Field and Compilation Sheets

Film contacts from the repromat of the NZMS 174 1:20 000 topo series (28 sheets) were brought to Western Samoa from New Zealand. These sets consisted of one film positive of black and blue detail combined (culture, drainage, grid) and one film of the brown data (contours and road fill). The original intention had been to make stable-based diazo transparencies for all compilational use, and for field sheets.

With the change to computer production of the maps, the need for dimensional exactness of compilation became less important and printed copies of the 1:20 000 maps were used for much field and compiling work.

The existence of such good topographical coverage, albeit outdated in some areas, was a vital factor in achieving consistent field and compilational results.

6.3 THE MAPPING PROGRAMME

6.3.1 Compilation Data Sources

(a) *Topographical base and cadastre* - the existing 1:20 000 series provided an excellent topographical framework, albeit outdated in places but entirely adequate for the 1:50 000 mapping and GIS database. Conversion data were freely available from DLS to place the WSIG (the new Western Samoa Integrated Grid), grid and sheetlines (to comply with newer 1:50 000 topo mapping under preparation in DLS) relative to detail and to place marginal graticule values.

The cadastral records in DLS (and to a much lesser extent in DAFF), proved satisfactory in plotting up the interfacing boundaries of the land categories.

(b) *Soils* - soil compilations consisted of punched, registered draughting film overlays on the film topographical bases onto which the soil scientist directly compiled as a one-step operation following field work and re-appraisal of Wright's 1963 survey.

(c) *Land Use* - initially, the sole data source was a detailed airphoto interpretation updating the printed topographical maps (by the project cartographer). The reliability was variable due to different ages and scales of photography. Also, it was not possible to perceive underplantings of coconut with other tree crops. Field surveys proved extremely difficult due to lack of physical vantage points with a clear view not obstructed by coconuts or other tall growth. The airphoto interpretation was supplemented by field data from DAFF agriculture extension officers. As none of these officers had formal map compilation training, the data was of very variable quality and was used judiciously to amend the photo interpretation. This theme of data was perhaps the most difficult of the project to complete.

(d) *Land Capability* - this compilation was produced by cross-referenced 1:50 000 computer map plot outs, which showed the soil boundaries with their capability label rather than soil label. These plots then required editing to remove soil boundaries between polygons with the same capability value, repositioning of labels, etc. This was greatly assisted by the Soil Scientist who had manually marked up and labelled the polygons as a film overlay to the soil compilations at 1:20 000 scale.

(e) *General Map Information* (legend, scale, notes etc.) - this data was compiled from information supplied by DLS and following normal cartographic conventions.

(f) *Thematic Legends* - the Land Use/Tenure legend was simple and open enough to computer-generate for direct plotting. All other legends were typed to disk and produced on the N.Z. Government Printer's "Penta" system by Science Mapping Unit, DSIR.

6.3.2 Establishing the Map Specification (see Appendix 11)

Unlike a normal cartographic specification, recognition of computer production needed to be written in with system limitations the governing factor. Classes of road were eliminated and the specification written in narrative style to serve also as a GIS training tool. Further, the realities of final production (plotter films) meant deviation to achieve a graphical balance with pens available.

The other factors governing specification were:

- need for simplicity under the complex thematic overlays
- knowledge that a simple specification is much easier to upgrade in the future with new data, while giving an adequate base for thematic overlaying.

6.3.3 Cartographic Editing Procedures

Normal rigorous standards of cartographic editing were maintained at all times. The following routine was established:

- each 1:20 000 cover (soils, topo, land use/tenure) for each of the 28 sheets in the topographical series was individually edited and physically edge matched for gross errors from a paper plot out. Total: 84 check plots. (The topo and land use/tenure plots had names/labels added at this first checkplot stage).

- Following linkup to form Upolu and Savaii databases for each theme, a plotout was made for each 1:50 000 sheet area for Upolu (3 sheet areas), and for the three topo covers of Savaii. For the remaining covers (soil, land use/tenure) continuous plots of Savaii at 1:75 000 were made.

- For the land capability cover, the first check plot was created as a software product, i.e., the labelled soilplot was replotted with labelling converted to capability codings. These plots then needed the marking up of soil boundaries to be deleted and relocation of most of the labels (with subsequent editing as for the other covers). The capability plots were computer-generated at a stage when the soilplots at 1:50 000 were labelled and through the "first correction" phase.

- As the 1:50 000 and 1:75 000 checkplots were edited and corrected, a further checkplot was made on paper.

- Following this, the final plotouts on film (for reproduction) were made.

To summarise: each area had four or five edits through compilation stages to final plotout for printing, a total of approximately 150 edited plotouts.

NOTE: Errors in the complex covers were revealed in the final plots. The rigorous editing employed is a normal cartographic procedure for map production. It is doubtful if such rigorous procedures would be used for straight GIS database production, particularly if highly-skilled cartographic input was not used. Clearly such databases would be of very dubious value.

6.3.4 Final Map Output

Each of the six 1:50 000 areas had five plotouts

Topography
Soils
Land Use
Land Tenure
Land Capability

In printing, the topography (base maps) appears on each of the three thematic maps. Land use and land tenure, while appearing on the same map, were separately plotted and printed in different colours for clarity.

The plots were taken to New Zealand, thematic legends set in New Zealand earlier were attached, a final edit of Soil and Land Capability was carried out with the Project Soil Scientist and the maps were submitted to the Government Printer for lithography. The size of the final maps (trimmed size) is:

820 mm wide x 845 mm deep (landuse, land capability)
1040 mm wide x 845 mm deep (soils)

The maps are printed on 90 gsm Mataura map paper which will withstand rigorous field use.

6.4 GIS

6.4.1 System Choice

The GIS system was chosen with particular emphasis on -

(1) Easily maintainable hardware and software,

(2) Adequate capacity for the proposed GIS and reasonable expansion.

(3) Flexibility for future development.

(4) Ease of use.

(5) Moderate cost (as far as consistent with the other criteria).

Criterion 1 (and to a lesser extent 5) strongly favoured a PC based system using standard commercial software. The size of the database and the likely nature and volume of applications were well within the capacity of an "AT" system and more sophisticated hardware (micro-channel-based systems, RISC workstations etc) would have proved much more difficult to maintain in Western Samoa.

The timetable for the project made it essential to have two computers (so that data capture and data editing could be performed simultaneously and to provide system redundancy in the event of equipment failure). The computers selected were -

(1) NOVACAD 386 with 2 Mbyte RAM and 64 Mbyte hard disk

(2) NOVACAD 286 with 1 Mbyte RAM and 40 Mbyte hard disk

Peripherals purchased were

(3) GTCO Digipad 5 digitiser with 16 button cursor

(4) EPSON LQ2550 dot-matrix printer (capable of colour graphics)

No plotter was purchased for the GIS as the system was connected to an existing HP Draftmaster II plotter at DLS.

The major software product selected was PC ARC/INFO (ESRI). This system was selected as one of the more widely used GISs with good map production and database management facilities as well as data manipulation, the ability to exchange data with a wide range of other GIS and image processing systems and with the potential to upgrade to a similar workstation or mainframe product if required.

PC-ARC/INFO was supplemented by EPPL7 (Minnesota Land Management Information Center - a compressed raster GIS), ALES (Cornell University - automatic land evaluation system, SURFER and GRAPHER (Golden Software - three dimensional modelling and general graphics package) and ultimately by TURBO-PASCAL (Borland) which was used to write programs to do anything not satisfactorily covered by the other packages. All these products were modestly priced.

6.4.2 Initial Site Setup and System Establishment

The above hardware and software was set up in DLS. PC-ARC/INFO was installed on the 386 computer and the other products on the 286. A custom program was written for "stream digitising" which met the data capture requirements of the project better than the standard ARC-INFO ADS routine. This program was installed on the 286 computer which was then connected to the digitiser.

A set of macros (and operating procedures) were written for transferring data captured to the PC-ARC/INFO system (386 computer) and for generating check plots of the transferred data. The operating procedures ensured that the diskettes used for data transfer automatically became backup diskettes and hence a separate diskette was used for each 1:20 000 sheet.

6.4.3 Database Establishment

The most important part of establishment a database (after initial data capture) is verifying and correcting the data. For a GIS this is an essentially cartographic task and the procedures are described in 6.3.5.

The second component is the organisation of the data. A major aspect of this organisation was the compilation of the 28 1:20 000 sheets into two whole island coverages (from which the six 1:50 000 plots were subsequently produced). This operation is also described in 6.3.5.

Production of the GIS databases was completed by generating "polygon coverages" for land tenure, land use and soils. Land capability was defined as a "feature" of the soil class. Additional soil properties (drainage class, moisture deficit, rooting volume, texture, pH, nutrient class, slope, surface stoniness and rock outcrops) were also assessed for each soil series and were stored in a relational "look up table" associated with the ARC/INFO GIS.

The ARCINFO polygon covers and the coastline, rivers and roads. Line covers were then exported to the EPPL7 system (installed on the 286 computer) for use with raster-based analysis techniques (polygon overlay etc). The soil data listed above was also stored in the ALES land evaluation system along with basic models giving the general land suitability for each of forestry, pasture, tree crops, root crops and vegetable crops.

6.4.4 Future System Development

The current GIS database contains all the information shown on the maps and has topologically structured polygon coverages of land use, tenure and soil. The database also includes specific information on soil properties based on the primary soil class mapped. Raster-based copies of the polygon coverages and of appropriate linear "base" features are installed on the 286 computer.

Revision and extension of the main database should be carefully planned. The present 386 computer could accommodate about twice its current data volume without noticeable performance degradation but database integrity must be a primary consideration. Any modification to the main database should be undertaken only by (or under the close supervision of) the system manager. Unfortunately a PC (MS-DOS) based system does not provide any mechanism for restricting file access.

The consultants recommend that the 386 computer (containing the database) should be used primarily for producing "custom" plots of any combination of database themes at any required scale. More sophisticated analysis operations (graphic overlay, buffering, etc) should be run on the 286 computer using the raster data copies. The problem is not so much the possibility of total data loss (full backups of the database are held) as undetected corruption of the data.

These constraints on system use are not seen as serious given the two computers in the system. These constraints can however be overcome by going to a more sophisticated multi-user computer system, storing the main database on CD-ROM or similar media or by exporting copies of the database to further computers.

As discussed above (section 6.4.1) more sophisticated computers are not (at present) seen as appropriate for Western Samoa. CD-ROM storage for the main database should be seriously considered for the future as this will ensure data integrity and hence allow more freedom for data manipulation on the 386 computer. This is a rapidly evolving technology, however, and the appropriate time to move this way may be in the next year or two when some experience on system use has accumulated.

The database (in whole or part) can be easily exported to other computers running possibly quite different software. The raster copy on the 286 computer is an example of such an operation. The great advantage of this approach is that it avoids conflict between uses of the system and allows much wider access to the data with no risk that one user can corrupt another user's (on a different computer) data. There is also much greater capacity for extending applications as there is no requirement that any one computer support all applications.

Expansion of the number of computers (and sites) used in the system would allow the use of image-processing systems, a full cadastral database, statistical databases etc to all be fully implemented on PC systems. Data transfer between such systems is simple and the frequency of data update is not very great. Such a "system" does however require that issues of data ownership and custodianship are resolved in such a way that

(1) There is no ambiguity as to which copy of any database is the master, and that all data revision is done on the master copy.

(2) Unauthorised copies of valuable or sensitive databases are not distributed to third parties.

6.5 CONCLUSIONS

6.5.1 Achievements

The establishment of a 1:50 000 prime scale database covering topo, some cadastre, land use/tenure and land capability is seen as a unique achievement given the time frame. The software routines operate satisfactorily and many DAFF, DLS, Treasury and other government officers have been successfully introduced to the system through regular contact, visits and seminars.

Strong earlier links between Western Samoa, DSIR and ANZDEC have been renewed and a fresh understanding in terms of the "new technology" developed. This should flow on into a strong regional GIS impact to assist land-use planning with this new tool.

6.5.2 Future requirements

These take two main forms:

(1) Continuing external assistance through more contact from New Zealand and regular in-country visits will be essential to support the GIS, particularly to ensure more Samoan trainees are able to avail themselves of overseas GIS training. The local managers and trainees will need a continuing inflow of overseas concepts to assess and implement in there own setting.

(2) Continuing recognition by all the agencies of Government that they need to work and budget cooperatively to ensure the health of what is a unique, country-wide national archive, and to ensure its proper housing, management and security.

SECTION 7: USING THE INFORMATION AND SYSTEMS

A geographic information system (GIS) requires a structured, scientific approach to problem-solving to bring benefits. For Western Samoa these benefits include revenue-earning aspects both internally and in ventures such as providing a quality digitising service for other countries (taking advantage of Western Samoa's cheap labour rate and favourable export exchange rates). The concept of a multi-use system is promoted.

7.1 SYSTEM MANAGEMENT AND MAINTENANCE

It is vital that the system be well maintained. To this end, the Consultants have recommended to the implementing agencies the type of local system support for which budgetary provision should be made annually. This advice has been accepted.

The Consultants also made recommendations on the qualities and level of a System Manager and on access to and security of the system as a national asset.

Also a possible T.A. Extension was discussed in detail between the Western Samoa Government, the consultants and the ADB for a two year technical support in home time and country visits for a computer scientist and spatial data handling / graphic design specialist.

7.2 POTENTIAL USERS

While the expert use of the system will see improved land planning decisions flowing directly to Samoan people living on the land, there is also potential for village and/or district groups to acquire maps to fit their particular needs and perhaps help resolve the vexing question of disputed customary land boundaries. Although outside the scope of this T.A. the lack of fully recognised community boundaries is seen as a brake on land development in some areas which GIS with its more user-friendly approach to mapping could help overcome.

The main users of GIS in the immediate future are seen as:

7.2.1 DAFF

For spatial display of a wide range of land use, land economy and land planning data and for use as a forestry planning tool.

7.2.2 DLS

For producing smaller-scale derived maps based on the topography in the GIS, for eventually digitising their cadastral records and for use by the recently formed Environmental Division.

7.2.3 Department of Economic Development

For spatially modelling economic statistics, trends, access relative to development, etc.

7.2.4 Department of Rural Affairs

Modelling of rural statistics.

7.2.5 Department of Statistics

Spatial modelling a wide range of population and related statistics.

7.2.6 Communities and Villages

Through a major agency such as DAFF, a pilot scheme could be initially run to map a village's (or group of villages') land with soil and capability data as a basis for discussion by community leaders on land development in their area. The map could be supplemented with additional data arising from discussion and with additional topo-cadastral data.

7.2.7 Private Sector

An effort could be made to publicise the GIS to the land-based business sector and institutions such as USP Alafua offering products from the GIS. This could be an important source of revenue. Other groups such as churches with large organisations could have their own management databases created relatively easily.

7.2.8 WSTEC

A proposal could be discussed with WSTEC to model all their estates on a separate database.

APPENDIX 1: SOIL MAP UNITS ARRANGED PHYSIOGRAPHICALLY AND CORRELATION WITH WRIGHT (1963)

		Map Symbols of Wright (1963) 1:100 000	1:20 000
SOILS OF THE COASTLANDS, VALLEY FLOORS AND THEIR MARGINS			
from saline estuarine sand and clay			
poorly drained			
1	Loga sandy clay	39	LG
1a	Loga peaty sand	39	LG1
from basaltic beach sand			
excessively drained			
2	Lufi sand	30	L
2a	Lufi gravelly sand	30	L1
from calcarious sand			
excessively drained			
3	Fusi sand	31	F, F1
3a	Fusi shallow grey sand over basalt	31a	F2
3b	Fusi stony and bouldery sand and stony clay	31a	F3
poorly drained			
4	Mutiatele mottled sand	32	M
4a	Mutiatele peaty loamy sand and sandy peat	32	M1
from estuarine sediment and organic residue			
imperfectly to poorly drained			
5	Apia silty clay	33	A, A1, A3
6	Namoa clay loam	34	N, N2
6a	Namoa peaty silt loam	34	N1, A2
6b	Namoa shallow peaty clay over basalt	34	N3
from organic residues			
poorly drained			
7	Lalovi peat	37	LV
8	Latalua loamy peat	38	LL
from basic alluvium			
well drained			
9	Sauniatu gravelly sandy clay loam	26	S, S2
9a	Sauniatu silty clay loam	26	S1
somewhat excessively drained			
9b	Sauniatu loamy sand	26	S3

imperfectly drained

10 Vaiola silty clay loam and gravelly loam	27	V

well to moderately well drained

11 Falevao silty clay loam	28	FV
11a Falevao slightly mottled silty clay loam	28	FV1

from basic colluvium

well drained

12 Ma'asina stony clay	29	MA
12a Ma'asina stony and bouldery clay	29	MA1
12b Ma'asina very bouldery clay	29	MA2
12H Ma'asina hill soils	29h	MA3

poorly drained

13 Vaigafa silty clay loam	35	VG, VG1
14 Lano silty clay loam and peaty clay loam	36	LO

from any parent material

well to moderately well drained

15 Man made soils

from recent alluvium, colluvium and organic residue

poorly drained

16 Palapala peaty loam	45	PP

SOILS OF THE LOWLANDS AND FOOTHILLS

(i) With weak to strong dry season (Udic moisture regime)

1. Soils of the very slightly dissected landscapes

from mainly pahoehoe basalt of the Aopo Volcanics

excessively drained

17 Matavanu sandy and fine gravel	24
17a Matavanu stony gravel	24a
17aH Matavanu hill soils	24h

from mixed pahoehoe and aa basalt of the Aopo Volcanics

excessively drained

18 Aopo loamy sand	25
18H Aopo hill soils	26h

from mainly pahoehoe basalt of the Puapua Volcanics

somewhat excessively drained

19 Falealupo very bouldery silty clay loam	1, 1a
19A Falealupo very bouldery silty clay loam, peaty phase	1b
20 Pulea very bouldery silt loam	1c

well drained

21	Sasina very stony and bouldery silty clay loam	4	
21H	Sasina hill soils		

from mainly scoria of the Puapua volcanics

somewhat excessively drained

22H	Alataua hill soils	1H	
22S	Alataua steepland soils	1S	

2. Soils of the slightly dissected landscapes

from aa and pahoehoe basalt and scoria of the Mulifanua Volcanics

well drained

23	Vaisala very stony silt loam	2	
23H	Vaisala hill soils	2h	
24	Sataua very stony silty clay loam	2a	ST
24a	Sataua very bouldery silty clay loam	2a	ST1, ST2
24H	Sataua hill soils	2ah	ST3
25	Saleimoa very stony silty clay loam	5	SE, SE3
25a	Saleimoa very bouldery silty clay loam	5	SE1, SE2, SE4
25H	Saleimoa hill soils	5h	SE5

from scoria and basalt of the Mulifanua Volcanics

well drained

26H	Neiafu hill soils	2H	
26S	Neiafu steepland soils	2S	
27H	Mulifanua hill soils	5H	MF1
27S	Mulifanua steepland soils	5S	MF

somewhat excessively drained

27V	Mulifanua steepland soils, very steep phase	5T	MF2

from mixed aa and pahoehoe basalt of the Mulifanua Volcanics

well drained

28	Magia stony clay loam	2b	MG
28a	Magia bouldery clay loam	2b	MG1, MG2
29	A'ana stony silty clay	5a	AA
29a	A'ana very stony silty clay loam	5a	AA1
29h	A'ana bouldery silty clay	5a	AA2
29c	A'ana shallow bouldery silty clay loam	5a	AA3
29H	A'ana hill soils	5ah	

3. Soils of the moderately dissected landscapes

from scoria basalt of the Salani Volcanics

well drained

30H	Olomanu hill soils	6H	OL1
30S	Olomanu steepland soils	6S	OL

from mixed pahoehoe and aa basalt of the Salani Volcanics

well drained

31	Vailele stony silty clay loam	6	VE

from mainly pahoehoe basalt of the Salani Volcanics

well drained

32	Moamoa stony clay	6a	MO, MO1

4. Soils of the strongly dissected landscapes

from pahoehoe, aa, scoria and dykes of basalt of the Fagaloa Volcanics

well drained

33	Vaipouli silty clay loam	18	VU
34H	Vaipapa hill soils	18h	VU1, VP1
34S	Vaipapa steepland soils	18S	VP

(ii) Without dry season (Perudic moisture regime)

1. Soils of the very slightly dissected landscape

from mainly pahoehoe basalt of the Puapua Volcanics

somewhat excessively drained

35	Togitogiga very bouldery silty clay loam	7a	TG, TG1
35a	Togitogiga very stony humic silt loam	7b	TG2
35H	Togitogiga hill soils	7ah	

well drained

36	Afuiva very bouldery silt loam	7c	AI
36H	Afuiva hill soils	7ch	AI1
37	Asoleilei stony silt loam	13	
37H	Asoleilei hill soils	13h	

from mainly scoria basalt of the Puapua Volcanics

well drained

38	Puna gravelly clay loam	7	PU
38H	Puna hill soils	7h	PU1
39H	Tanutala hill soils	7H	TN1
39S	Tanutala steepland soils	7S	TN

2. Soils of the slightly dissected landscapes

from aa, scoria and pahoehoe basalt of the Le Faga Volcanics

well drained to somewhat excessively drained

40	Lefaga stony silty clay loam	8	LE, LE1
40a	Lefaga bouldery silty clay loam	8	LE2, LE3
40H	Lefaga hill soils	8h	LE4
41	Tanumalala stony silty clay loam	8a	TU
41a	Tanumalala very stony silty clay loam	8a	TU1
41b	Tanumalala very bouldery silt loam	8a	TU2, TU3
41H	Tanumalala hill soils	14a	TU4
42	Atua very bouldery silty clay loam	14a	AT
42H	Atua hill soils	14a	AT1

from scoria basalt of the Mulifanua Volcanics

well drained

43H	Olo hill soils	9H	OO1
43S	Olo steepland soils	9S	OO
43V	Olo steepland soils, very steep phase	9T	OO2
44H	Fa'amasa hill soils	15H	FA1
44S	Fa'amasa steepland soils	15S	FA
44V	Fa'amasa steepland soils, very steep phase	15T	FA2
45	Tapuele silty clay	15	TE

from mixed as and pahoehoe basalt of the Mulifanua Volcanics

well drained

46	Tafatafa very stony silty clay loam	9a	TF
46a	Tafatafa bouldery silty clay loam	9a	TF1, TF2
46b	Tafatafa very bouldery silty clay loam	9a	TF3
46H	Tafatafa hill soils	9ah	TF4
47	Aleisa very stony silty clay loam	9b	AE, AE1
47a	Aleisa very bouldery silty clay loam	9b	AE2
47H	Aleisa hill soils	9bh	AE3
48	Salailua very stony silty clay loam	15a	SU
48a	Salailua bouldery silty clay	15a	SU1
48H	Salailua hill soils	15ah	SU2
49	Gaegae very stony silty clay loam	15b	GG
49a	Gaegae very bouldery silty clay loam	15b	GG1
49H	Gaegae hill soils	15bh	GG2

3. Soils of the moderately dissected landscapes

from calcareous lithic tuffs of the Vini Volcanics

well drained

50	Vini clay	22	VN
50H	Vini hill soils	22h	VN1
51H	Nu'utele hill soils	22H	NT1
51S	Nu'utele steepland soils	22S	NT
51V	Nu'utele steepland soils, very steep phase	22T	NT3

from lithivitric tuffs and ash of the Vini Volcanics

well drained

52	Tafua silty clay loam	23	
52H	Tafua hill soils	23h	
53S	Folu steepland soils	23S	

from scoria aa of the Mulifanua and Salani Volcanics

well drained

54H	Mulimauga hill soils	10H	ML1
54S	Mulimauga steepland soils	10S	ML
55	Olomauga stony silty clay	10	OM
55H	Olomauga hill soils	10h	OM1
56	Fagapolo silty clay	16	FO
57H	Tiotala hill soils	16H, 16h	TT1, FO1
57S	Tiotala steepland soils	16S	TT
57V	Tiotala steepland soils, very steep phase	16T	TT2

from mixed pahoehoe and aa of the Salani Volcanics

well drained

58	Papauta silty clay	11	PA
58a	papauta stony silty clay	11	PA1
58b	Papauta bouldery silty clay	11	PA2
58H	Papauta hill soils	11h	PA3
59	Avele stony silty clay loam	11a	AV
59a	Avele very stony silty clay loam	11a	AV1
59b	Avele bouldery silty clay loam	11a	AV2
59H	Avele hill soils	11ah	AV3
60	Solosolo silty clay loam	17	SO
60a	Solosolo stony and bouldery clay	17	SO1
61H	Salani hill soils	17aH, 17h, 17H	SN1, SO2, SL
61S	Salani steepland soils	17aS	SN
61V	Salani steepland soils, very steep phase	17AT	SN2
62	Etemuli silty clay loam	17a	ET
62a	Etemuli very stony silty clay loam	17a	ET1
62b	Etemuli very bouldery silty clay loam	17a	ET2
62H	Etemuli hill soils	17ah	ET3

from mainly pahoehoe of the Salani Volcanics

well drained

63H	Aleipata hill soils	12H	AL1
63S	Aleipata steepland soils	12S	AL
63V	Aleipata steepland soils, very steep phase	12T	AL2
64	Falealili silty clay loam	12	FL
64a	Falealili stony silty clay loam	12	FL1, FL3, FL4
64b	Falealili very stony silty clay loam	12	FL2, FL5, FL6
64H	Falealili hill soils	12h	FL7
65	Fagaga silty clay loam	12a	FG
65a	Fagaga stony silty clay loam	12a	FG1
65b	Fagaga very stony silty clay loam	12a	FG2
65H	Fagaga hill soils	12ah	FG3

4. Soils of the strongly dissected landscapes

from pahoehoe, aa, scoria and dykes of basalt of the Fagaloa Volcanic

well drained

66H	Papaloa hill soils	19H	PL1, PL3, SA2
66S	Papaloa steepland soils	19S	PL
66V	Papaloa steepland soils, very steep phase	19T	PL2
67	Sauaga clay	19	SA
67H	Sauaga hill soils	19h	SA1
68	Luatanu'u clay	19a	LU
68a	Luatanu'u clay, eroded phase	19b	LU1
68H	Luatanu'u hill soils	19ah	LU2
69H	Upolu hill soils	21H, 11	UP1, VL, VL1
69S	Upolu steepland soils	21S	UP
69V	Upolu steepland soils, very steep phase	21T	UP2
70	Tuave clay	21	TV
70H	Tuave hill soils	21h	TV1

from pahoehoe, aa and dykes of basalt of the Fagaloa Volcanics

well drained

71H	Lata hill soils	20H	LA1
71S	Lata steepland soils	20S	LA
71V	Lata steepland soils, very steep phase	20T	LA2
72	Uafato silty clay	20	UA

72H Uafato hill soils	20h	UA1

SOILS OF THE UPLANDS

1. Soils of the very slightly dissected landscapes

from mainly pahoehoe basalt of the Aopo Volcanics

excessively drained

74 Mu gravel	44	
74H Mu hill soils	44h	

from scoria and pahoehoe basalt of the Puapua Volcanics

well to moderately well drained

75 Maugamoa very bouldery peaty silt loam	40	
75H Maugamoa hill soils	40h	
76S Mafane steepland soils	40S	
77 Samoa gravelly bouldery loam	46	
78S Savai'i steepland soils	46S	

2. Soils of the slightly dissected landscapes

from aa, scoria and pahoehoe basalt of the Mulifanua Volcanics

well to moderately well drained

79 Salega humic stony silt loam	41	
79H Salega hill soils	41h	
80H Elitoga hill soils	41H	
80S Elitoga steepland soils	41S	
81 Sili stony loam	47	
82H Maugasili hill soils	47H	
82S Maugasili steepland soils	47S	

3. Soils of the moderately dissected landscapes

from scoria basalt of the Salani Volcanics

well drained

83 Afiamalu silt loam	42	AF
83H Afiamalu hill soils	42h	AF1
84H Lanuto'o hill soils	42H	LN1
84S Lanuto'o steepland soils	42S	LN
84V Lanuto'o steepland soils, very steep phase	42T	LN2

from mixed aa and pahoehoe basalt of the Salani Volcanics

well drained

85 Tiavi silty clay loam	42a	TA
85a Tiavi stony silty clay loam	42a	TA1
85b Tiavi stony and bouldery silty clay loam	42a	TA2
85H Tiavi hill soils	42h	TA3

from scoria, pahoehoe and aa basalt of the Salani Volcanics

moderately well drained

86S Mata'ana steepland soils	48	

APPENDIX 2: KEY TO WESTERN SAMOAN SOIL SERIES

EXPLANATION:
Y = Yes: read next question
N = No: refer to question number listed after N
(103) = Soil series map number
For definitions of the terms isohyperthermic, isothermic, udic, perudic, and aquic refer to 3.3.2: Climate.

1.	Has the soil an isohyperthermic temperature regime?	Y	N 103
2.	Does the soil occur have a udic moisture regime?	Y	N 39
3.	Does the soil occur in the coast land or valley floors and their margins?	Y	B14
4.	Does the soil occur in the coastal fringe?	Y	N 14
5.	Does the soil occur in tidal estuarine inlets?	Y Loga series (1)	N 6
6.	Does the soil occur on beaches?	Y	N 11
7.	Is the soil formed in basaltic sand and is it excessively drained?	Y Lufi series (2)	N 8
8.	Is the soil formed in calcareous sand?	Y	N 11
9.	Is the soil excessively drained?	Y Fusi series (3)	N 11
10.	Is the soil poorly drained	Y Mutiatele series (4)	N 9
11.	Does the soil occur on former estuarine flats?	Y	N 14
12.	Is the soil imperfectly drained?	Y Apia series (5)	N 13

13. Is the soil poorly drained?
Y Namoa series (6) N 14

14. Does the soil occur in wet lowland depressions?
Y Lalovi series (7) N 15

15. Does the soil occur on mainly flattish recent lava flows?
Y N 18

16. Does soil material consisting of sand and fine gravel only occur in few cracks in the pahoehoe?
Y Matavanu series (17) N 17

17. Does soil material consisting of stony silt loam or loamy fine sand occur in hollows and as a thin layer over most of the area?
Y Aopo series (18) N 18

18. Does the soil occur on flattish young lava flows with large areas of bare lava?
Y N 23

19. Is the soil very bouldery and stony silty clay loam overlying pahoehoe lava at 50 cm depth (somewhat excessively drained) with black to very dark brown (10YR) topsoils?
Y Falealupo series (19) N 20

20. Does the soil occur on flattish rough surfaces with undulating to rolling topography?
Y N 23

21. Is the soil very bouldery silt loam (somewhat excessively drained) with very dark brown topsoils (7.5YR)?
Y Pulea series (20) N 22

22. Is the soil bouldery and stony at the surface with 40 to 70 percent silty clay loam till 50 cm depth?
Y Sasina series (21) N 20

23. Does the soil occur on lowland scoria cones consisting of abundant vesicular boulders and stones? (somewhat excessively drained)
Y Alataua series (22) N 24

24. Does the soil occur on flat to rolling lowland?
Y N 30

25. Is the soil very stony with very dark grey (10YR 3/1) silt loam to at least 50 cm depth?
Y Vaisala series (23) N 26

26. Is the soil very stony and bouldery silt loam to silty clay loam overlying pahoehoe lava at more than 50 cm depth?
Y Sataua series (24) N 27

27. Is the soil stony and bouldery to 100 cm or more depth with black silty clay loam forming 50% or more of the matrix?
Y Saleimoa series (25) N 28

28. Is the soil formed from dark reddish brown scoria on hilly to steep slopes?
Y Neiafu series (26) N 29

29. Does the soil occur on steep to very steep scoria cones with dark reddish brown and yellowish red scoria forming more than 50 percent of the soil profile?
Y Mulifanua series (27) N 30

30. Does the soil occur on flat to rolling coastal lowlands with stony and bouldery surfaces?
Y N 36

31. Has the soil weakly vesicular stones less than to 50% of the dark brown silty clay soil profile?
Y Magia series (28) N 32

32. Has the soil less than 50% stones in the dark greyish brown silty clay loam?
Y A'ana series (29) N 33

33. Has the soil less than 35% stones in a dark brown silty clay loam topsoil overlying dark yellowish brown silty clay loam and silty clay?
Y Vailele series (31) N 34

34. Has the soil a stony and bouldery surface and does the soil consist of reddish clay?
Y Moamoa series (32) N 35

35. Does the soil occur on small volcanic cones and has it few stones in the soil profile consisting of dark reddish brown silt loam?
Y Olomanu series (30) N 36

36. Does the soil occur in a strongly dissected landscape?
Y N 39

37. Does the soil occur on plateaus in northeastern parts of Savai'i and has it dark brown (7.5YR) colours?
Y Vaipouli series (33) N 38

38. Does the soil occur on steep or hilly slopes related to plateaus and do soils consist of dark brown (7.5YR) silty clay?
Y Vaipapa series (34) N 39

39. Does the soil occur in a perudic moisture regime?
Y N 2

40. Is the soil formed in basaltic alluvium?
Y N 44

41. Does the soil occur on river flats, is it well drained and do the soils consist of dark greyish brown silty clay loam?
Y Sauniatu series (9) N 42

42. Does the soil occur on valley floors, is it imperfectly drained, with dark yellowish brown topsoils?
Y Vaiola series (10) N 43

43. Does the soil occur in former river plains and is the soil profile free of gravels and stones?
Y Falevao series (11) N 44

44. Is the soil formed in colluvium?
Y N 50

45. Does the soil occur in fans at footslopes of hill country, is the soil well drained and are there many stones and boulders at the surface and in the soil?
Y Ma'asina series (12) N 46

46. Is the soil poorly drained and does it occur in upland depressions at the headwaters of the Salani River?
Y N 50

47. Has the soil pale brown and pale grey colours overlying pahoehoe lava?
Y Vaigafa series (13) N 48

48. Does the soil occur in volcanic crater floors and has the soil reddish colours?
Y Lano series (14) N 49

49. Does the soil occur in coastal depressions and does it consist of fibrous peat overlying peaty loam?
Y Latalua series (8) N 50

50. Does the soil occur in flat to easy rolling coastal lowlands?
Y N 52

51. Is the soil very bouldery (excessively drained) with 7.5YR hues in the topsoil?
Y Togitogiga series (35) N 52

52. Does the soil occur on flattish inland lowlands?
Y N 55

53. Is the soil stony and bouldery and well drained with dark brown (7.5YR) topsoils?
Y Afuiva series (36) N 54

54. Has the soil less than 50% stones on a lithic contact between 50 and 100 cm and has it a 7.5YR hue in the subsoil?
Y Asoleilei series (37) N 52

55. Does the soil occur on small volcanic cones in inland lowlands?
Y N 58

56. Is the soil formed from vesicular scoriaceous basalt and does it occur on easy rolling to hilly slopes with gravelly surfaces?
Y Puna series (38) N 58

57. Does the soil occur on steep to hilly slopes of volcanic cones in inland lowlands and has it 7.5YR colours throughout the soil profile?
Y Tanutala series (39) N 58

58. Does the soil occur on easy to strongly rolling lower foothills?
Y N 61

59. Has the soil 30 to 60% vesicular boulders increasing with depth and has the soil 10YR colours throughout the profile?
Y Lefaga series (40) N 60

60. Is the soil extremely stony and bouldery overlying massive pahoehoe basalt and is the soil dark brown (10YR 3/3) to the depth of the pahoehoe?
Y Tanumalala series (41) N 61

61. Does the soil occur in the flat to rolling upper to central foothills? (900 to 1600 feet)
Y N 72

62. Is the soil stony and bouldery with large boulders varying from 30 to 80 cm depth and is the soil a dark brown (10YR 3/3) silty clay loam?
Y Atua series (42) N 63

63. Is the soil very stony and bouldery with silty clay loam textures and pahoehoe lava at 30 to 50 cm depth?
Y Tafatafa series (46) N 64

64. Is the soil stony or bouldery with 20 cm or more black to very dark greyish brown topsoils?
Y Aleisa series (47) N 65

65. Is the soil stony or bouldery and is the soil a dark brown silty clay loam?
Y Salailua series (48) N 66

66. Is the soil very stony with a 7.5YR silty clay loam throughout the soil profile?
Y Gaegae series (49) N 67

67. Does the soil occur on steep to hilly slopes of scoria cones of the lower foothills?
Y N 68

68. Is the soil composed of reddish (5YR hue) scoria of up to 8 cm diameter?
Y Olo series (43) N 69

69. Has the soil abundant highly vesicular boulders and stones at the surface and has the soil profile 40 to 60% stones in a 7.5YR soil profile?
Y Fa'amasa series (44) N 70

70. Does the soil occur on rolling surfaces near scoria cones (Olo series and Falamasa series) with few stones in the upper horizons and 7.5YR hues in the soil profile?
Y Tapuele series (45) N 71

71. Does the soil occur on the smaller islands of Apolima, Fanuatapu, Namua, Nu'utele or Nu'ula?
Y N 74

72. Does the soil occur on steep or very steep slopes and has it a clay texture?
Y Nu'utele series (51) N 73

73. Does the soil occur on easy rolling, rolling or hilly slopes?
Y Vini series (50) N 74

74. Does the soil occur in the vicinity of Tafua Mountain in southeastern Savai'i?
Y — N 77

75. Is the soil deep and friable with few stones and 7.5YR colours in the subsoil?
Y Tafua series (52) — N 76

76. Does the soil occur on steep or very steep slopes with reddish brown (5YR) colours in the upper 25 cm?
Y Folu series (53) — N 77

77. Does the soil occur on scoria cones of the upper foothills? (moderately dissected)
Y — N 82

78. Does the soil occur on hilly or steep slopes?
Y — N 81

79. Has the soil dark reddish brown colours (5YR) and are there few scoria gravels in the upper horizons?
Y Mulimauga series (54) — N 80

80. Has the soil dark brown colours (10YR) with few to common stones in the profile?
Y Olomauga series (55) — N 81

81. Has the soil dark reddish brown to dark red colours (2.5YR) with few scoria fragments increasing with depth?
Y Tiotala series (57) — N 82

82. Does the soil occur on rolling to hilly slopes adjacent to scoria cones and has the soil reddish brown colours (5YR), is it gritty and do scoria fragments occur at 50 to 70 cm depth?
Y Fagapolo series (56) — N 83

83. Does the soil occur in a moderately dissected landscape? (with a large percentage of strongly rolling, hilly and steep slopes)
Y — N 94

84. Does the soil occur on broad flattish ridges in the lowlands?
Y — N 88

85. Has the soil profile dark brown (10YR) colours to at least 50 cm depth and is the profile stony with stones and boulders increasing with depth?
Y Papauta series (58) — N 86

86. Does the soil occur in the lower foothills, is it stony and bouldery with a lithic contact at 50 cm depth?
Y Avele series (59) N 87

87. Is the soil dark brown (10YR 3/3) to 100 cm depth or more?
Y Solosolo series (60) N 88

88. Does the soil occur on steep and hilly slopes of the foothills with stony and bouldery areas and an increase in clay content with increasing depth?
Y Salani series (61) N 89

89. Does the soil occur on flat to rolling plateaus of the upper foothills?
Y N 90

90. Have soil profiles dark brown topsoils overlying dark yellowish brown subsoils with strongly weathered basaltic gravels, stones or boulders?
Y Etemuli series (62) N 91

91. Does the soil occur on hilly and steep slopes of the upper foothills, with rocky and bouldery surfaces and the soil matrix composed of reddish brown (5YR to 7.5YR) weathered basalt?
Y Aleipata series (63) N 92

92. Does the soil occur on flat to rolling lowland terraces with very dark brown to dark brown (10YR) soil profiles?
Y Falealili series (64) N 93

93. Does the soil occur in rolling inland terraces with many surface stones and stony soil profiles, stones becoming abundant at 50 cm depth?
Y Fagaga series (65) N 94

94. Does the soil occur on strongly dissected landscapes?
Y N 103

95. Does the soil occur on broad ridges?
Y N 97

96. Is the soil free of stones and is it a dark brown silty clay to clay to 50 to 70 cm depth?
Y Sauaga series (67) N 97

97. Does the soil occur on steep or hilly slopes where the surface is free of stones or boulders and the upper horizons are free of stones except for few weathered fragments of basalt?
Y Papaloa series (66) N 98

98. Does the soil occur on narrow rolling to hilly plateaus, and have stoneless profiles with 7.5YR hues?
Y Luatuanu'u series (68) N 99

99. Do the soils occur on steep, very steep and hilly slopes with very bouldery and stony surfaces and stony and bouldery clayey profiles?
Y Upolu series (69 N 100

100. Does the soil occur on rolling to hilly upper foothill plateaus with clayey soils almost free of stones except for some weathered andesitic basalt fragments at about 100 cm depth?
Y Tuave series (70) N 101

101. Does the soil occur on rolling to hilly plateau remnants where strongly weathered andesitic basalt forms a paralithic contact at about 100 cm depth and soil profiles are stone-free with strong brown to yellowish brown colours in the subsoil?
Y Uafato series (72) N 102

102. Do the soils occur on steep to very steep and locally hilly slopes with stone-free profiles overlying weathered basalt at depth varying from 5 to 80 cm?
Y Lata series (71) N 103

103. Do the soils occur on the uplands (above 2000 feet) with an isothermic temperature regime?
Y N 117

104. Do the soils occur on young lava flows?
Y N 107

105. Is the soil composed of peaty gravel overlying coarse scoria gravel?
Y Mataoleafi series (73) N 106

106. Is the soil composed of dusky red peaty gravel and sand overlying large boulders of highly vesicular basalt?
Y Mu series (74) N 107

107. Does the soil occur on rolling to hilly uplands and have soil profiles with more than 50% stones and gravels with black to dark grey silt loam overlying dark reddish brown silty clay loam?
Y Maugamoa series (75) N 108

108. Do the soils occur on steep, very steep or hilly slopes of volcanic cones?
Y N 110

109. Is the surface slightly stony and bouldery and are the soil profiles composed of very dusky red peaty silt loam on brown and yellowish red subsoils with weakly weathered scoria increasing with increasing depth?
Y Mafane series (76) N 110

110. Do the soils occur on undulating to rolling and hilly upland free of stones?
Y N 110

111. Do the soils have humic silt loam topsoils and B horizons and if stony, is there more than 60% highly vesicular scoriaceous basalt?
Y Salega series (79) N 112

112. Does the soil occur on steep to hilly scoria cones with 20 to 40% surface stones and soil profiles have dark reddish brown peaty silt loam overlying dusky red silt loam overlying loosely packed scoria stones at about 50 cm depth?
Y Elietoga series (80) N 113

113. Do the soils occur on strongly rolling to hilly uplands and is the soil composed of dark reddish brown peaty silt loam, on stony brown and red subsoils with weathered scoria stones overlying weathered scoria?
Y Afiamalu series (83) N 114

114. Does the soil occur on large steep to very steep and hilly scoria cones with yellowish red topsoils and scoria occurring below 50 cm depth?
Y Lanuto'o series (84) N 115

115. Does the soil occur on upland plateaus, and have soil profiles with 10YR hues?
Y Tiavi series (85) N 116

116. Does the soil occur on flat upland depressions covered with water during heavy rain and is the soil peaty overlying colluvial silty clay loam?
Y Palapala series (16) N 117

117. Does the soil occur on undulating to rolling surfaces above 4000 feet?
Y N 120

118. Is the surface bouldery and stony and is the soil profile composed of very thin dusky red fibrous peat overlying reddish black very bouldery peaty loam?
Y Samoa series (77) N 119

119. Is the surface mainly free of stones and boulders and is the soil profile composed of thin dusky red fibrous peat overlying reddish silty clay with stones increasing with depth?
Y Sili series (81) N 120

120. Does the soil occur on steep to hilly slopes of volcanic cones above 4000 feet?
Y N 117

121. Are soil profiles composed of very dusky red fibrous peat, overlying reddish black silt loam on red bouldery and gravelly scoria?
Y Savai'i series (78) N 122

122. Are soil profiles composed of very dusky red peat overlying reddish brown bouldery silty clay loam and weathered scoria?
Y Maugasili series (82) N 123

123. Are soil profiles composed of 30 to 35 cm dusky red peat and peaty loam on brown to strong brown clay loam overlying yellowish red scoria at 100 to 180 cm depth?
Y Mata'ana series (86) N 124

124. Are the soils severely disturbed by human activity, or covered by concrete, asphalt etc?
Y Manmade soils N 1

APPENDIX 3: CLASSIFICATION OF SOIL SERIES ACCORDING TO SOIL TAXONOMY

Order	Great Group	Subgroup	Soil Name	Soil Family	Map Symbols
Histosols	Tropofibrists	+ Hydric	Lalovi peat	dysic, isohyperthermic	7
		+ Fluvaquentic	Latalua loamy peat	euic, isohyperthermic	8
Andisols	Fulvudands	o Lithic	Sataua very stony silty clay loam	medial-skeletal, amorphict, isohyperthermic	24
		* Lithic	Sataua very bouldery silty clay loam	medial-skeletal, amorphic, isohyperthermic	24a
		* Lithic	Sataua hill soils	medial-skeletal, amorphic, isohyperthermic	24H
		+ Lithic	Samoa gravelly bouldery loam	medial-skeletal, amorphic, isothermic	77
		+ Hydric Pachic	Maugamoa very bouldery peaty silt loam	medial-skeletal, amorphic, isothermic	75
		+ Hydric Pachic	Maugamoa hill soils	medial-skeletal, amorphic, isothermic	75H
		+ Hydric Pachic	Savai'i steepland soils	medial-skeletal, amorphic, isothermic	78S
		o Hydric Pachic	Salega humic stony silt loam	medial and medial-skeletal, amorphic, isothermic	79
		* Hydric Pachic	Salega hill soils	medial-skeletal, amorphic, isothermic	79H
		o Pachic	Vaisala very stony silt loam	medial-skeletal, amorphic, isohyperthermic	23
		* Pachic	Vaisala hill soils	medial-skeletal, amorphic, isohyperthermic	23H
		+ Pachic	Mafane steepland soils	medial-skeletal, amorphic, isothermic	76S
		o Pachic	Lanuto'o hill soils	medial and medial-skeletal, amorphic, isothermic	84H
		* Pachic	Lanuto'o steepland soils	medial-skeletal, amorphic, isothermic	84S
		* Pachic	Lanuto'o steepland soils, very steep phase	medial-skeletal, amorphic, isothermic	84V
		+ Eutric	Olo hill soils	medial-skeletal, amorphic, isohyperthermic	43H
		+ Eutric	Olo steepland soils	medial-skeletal, amorphic, isohyperthermic	43S
		+ Eutric	Olo steepland soils, very steep phase	medial-skeletal, amorphic, isohyperthermic	43V
		* Eutric	Fa'amasa hill soils	medial-skeletal, amorphic, isohyperthermic	44H
		o Eutric	Fa'amasa steepland soils	medial-skeletal, amorphic, isohyperthermic	44S
		* Eutric	Fa'amasa steepland soils, very steep phase	medial-skeletal, amorphic, isohyperthermic	44V
		o Acric	Atua very bouldery silty clay loam	medial-skeletal, amorphic, isohyperthermic	42
		* Acric	Atua hill soils	medial-skeletal, amorphic, isohyperthermic	42H
		o Acric	Gaegae very stony silty clay loam	medial-skeletal, amorphic, isohyperthermic	49
		* Acric	Gaegae very bouldery silty clay loam	medial-skeletal, amorphic, isohyperthermic	49a
		* Acric	Gaegae hill soils	medial-skeletal, amorphic, isohyperthermic	49H
		+ Acric	Mata'ana steepland soils	medial, amorphic, isothermic	86S
		o Typic	Olomanu hill soils	medial, amorphic, isohyperthermic	30H
		* Typic	Olomanu steepland soils	medial-skeletal, amorphic, isohyperthermic	30S
		* Typic	Lefaga stony silty clay loam	medial-skeletal, amorphic, isohyperthermic	40
		o Typic	Lefaga bouldery silty clay loam	medial-skeletal, amorphic, isohyperthermic	40a
		* Typic	Lefaga hills soils	medial-skeletal, amorphic, isohyperthermic	40H
	Hapludands	o Lithic	Togitogiga very bouldery silty clay loam	medial-skeletal, amorphic, isohyperthermic	35
		* Lithic	Togitogiga very stony humic silt loam	medial-skeletal, amorphic, isohyperthermic	35a
		* Lithic	Tongitogiga hill soils	medial over fragemental, amorphic, isohyperthermic	35H
		* Lithic	Tanumalala very stony silty clay loam	medial-skeletal, amorphic, isohyperthermic	41a

Order	Great Group	Subgroup	Soil Name	Soil Family	Map Symbols
		o Lithic	Tanumalala very bouldery silt loam	medial-skeletal, amorphic, isohyperthermic	41b
		* Lithic	Tanumalala hill soils	medial-skeletal, amorphic, isohyperthermic	41H
		o Alic	Puna gravelly clay loam	medial-skeletal, amorphic, isohyperthermic	38
		* Alic	Puna hill soils	medial-skeletal, amorphic, isohyperthermic	38H
		o Hydric	Tanutala hill soils	medial-skeletal, amorphic, isohyperthermic	39H
		* Hydric	Tanutala steepland soils	medial-skeletal, amorphic, isohyperthermic	39S
		+ Hydric	Sili stony loam	hydrous-skeletal, amorphic, isothermic	81
		+ Hydric	Maugasili hill soils	hydrous-skeletal, amorphic, isothermic	82H
		+ Hydric	Maugasili steepland soils	hydrous-skeletal, amorphic, isothermic	82S
		+ Eutric	Alataua hill soils	medial-skeletal, amorphic, isohyperthermic	22H
		+ Eutric	Alataua steepland soils	medial-skeletal, amorphic, isohyperthermic	22S
		o Eutric	Neiafu hill soils	medial-skeletal, amorphic, isohyperthermic	26H
		* Eutric	Neiafu steepland soils	medial-skeletal, amorphic, isohyperthermic	26S
Andisols	Hapludands	o Eutric	Tafua silty clay loam	medial, amorphic, isohyperthermic	52
		* Eutric	Tafua hill soils	medial over fragmental, amorphic, isohyperthermic	52H
		* Eutric	Folu steepland soils	medial over fragmental, amorphic, isohyperthermic	53S
		* Acric	Tanumalala stony silty clay loam	medial-skeletal, amorphic, isohyperthermic	41
		* Acric	Tanumalala very stony silty clay loam	medial-skeletal, amorphic, isohyperthermic	41a
		* Acric	Tanumalala very bouldery silty clay loam	medial-skeletal, amorphic, isohyperthermic	41b
		* Acric	Tanumalala hill soils	medial-skeletal, amorphic, isohyperthermic	41H
		+ Oxic	Tiotala hill soils	medial over clayey-skeletal, amorphic isohyperthermic	57H
		+ Oxic	Tiotala steepland soils	medial over clayey-skeletal, amorphic, isohyperthermic	57S
		+ Oxic	Tiotala steepland soils, very steep phase	medial-skeletal, amorphic, isohyperthermic	57V
		+ Oxic	Fagapolo silty clay	medial over clayey-skeletal, amorphic, isohyperthermic	56
		+ Typic	Mulifanua hill soils	medial-skeletal, amorphic, isohyperthermic	27H
		+ Typic	Mulifanua steepland soils isohyperthermic	medial-skeletal, amorphic,	27S
		+ Typic	Mulifanua steepland soils, very steep phase	fragmental, amorphic, isohyperthermic	27V
		o Typic	Magia stony clay loam	medial-skeletal, amorphic, isohyperthermic	28
		* Typic	Magia bouldery clay loam	medial-skeletal, amorphic, isohyperthermic	28a
		o Typic	Tapuele silty clay	medial over skeletal, amorphic, isohyperthermic	45
		* Typic	Upolu hill soils	medial-skeletal, amorphic, isohyperthermic	69H
		o Typic	Upolu steepland soils	medial-skeletal, amorphic, isohyperthermic	69S
		* Typic	Upolu steepland soils, very steep phase	medial-skeletal, amorphic, isohyperthermic (Lithic subgroups occur)	69V
		* Typic	Elietoga hill soils	medial-skeletal, amorphic, isothermic	80H
		o Typic	Elietoga steepland soils	medial-skeletal, amorphic, isothermic	80S
Oxisols	Acroperox	o Anionic	Fagaga silty clay loam	coarse silty, ferruginous, isohyperthermic	65
		* Anionic (humic)	Tuave clay	clayey, ferruginous, isohyperthermic	70
		o Anionic	Tuave hill soils	clayey, ferruginous, isohyperthermic	70H
	Haploperox	o Humic	Papaloa hill soils	clayey, kaolinitic, isohyperthermic	66H
		* Humic	Papaloa steepland soils	clayey, kaolinitic, isohyperthermic	66S

Order	Great Group	Subgroup	Soil Name	Soil Family	Map Symbols
		* Humic	Papaloa steepland soils, very steep phase	clayey, kaolinitic, isohyperthermic	66V
		+ Typic	Luatuanu'u clay	clayey, kaolinitic, isohyperthermic	68
		+ Typic	Luatuanu'u clay, eroded phase	clayey, kaolinitic, isohyperthermic	68a
		+ Typic	Luatuanu'u hill soils	clayey, kaolinitic, isohyperthermic	68H
	Acrudox	o Anionic	Vaipouli silty clay loam	clayey, gibbsitic, isohyperthermic	33
Mollisols	Hapludolls	o Cumulic	Apia silty clay	fine, oxidic, isohyperthermic	5
		* Fluventic	Sauniatu gravelly sandy clay loam	loamy-skeletal, oxidic, isohyperthermic	9
		o Fluventic	Sauniatu silty clay loam	fine loamy over sandy, oxidic, isohyperthermic	9a
		* Fluventic	Sauniatu loamy sand	sandy-skeletal, oxidic, isohyperthermic	9b
		o Andic	Sasina very stony and bouldery silty clay loam	medial-skeletal, oxidic, isohyperthermic	21
		* Andic	Sasina hill soils	medial-skeletal, oxidic, isohyperthermic	21H
		o Lithic	Aopo loamy sand	sandy-skeletal, mixed, isohyperthermic	18
		* Lithic	Aopo hill soils	fragmental, mixed, isohyperthermic	18H
		o Lithic	Falealupu very bouldery silty clay loam	loamy-skeletal, oxidic, isohyperthermic	19
		* Lithic	Falealupu very bouldery silty clay loam, peaty phase	loamy-skeletal, oxidic, isohyperthermic	19a
		o Lithic (andic)	Pulea very bouldery silt loam	clayey-skeletal, mixed (amorphic), isohyperthermic	20
		* Lithic	Vaipapa hill soils	fine, oxidic, isohyperthermic	34H
		o Lithic	Vaipapa steepland soils	fine, oxidic, isohyperthermic	34S
		+ Lithic	Mataoleafi gravelly sand	sandy-skeletal, mixed, isothermic	73
		+ Lithic	Mataoleafi gravel	fragmental, mixed, isothermic	73a
		+ Lithic	Mataoleafi hill soils	fragmental, mixed, isothermic	73H
		+ Lithic	Mu gravel	fragmental, mixed, isothermic	74
		+ Lithic	Mu hill soils	fragmental, mixed, isothermic	74H
Inceptisols	Tropaquepts	+ Lithic	Namoa shallow peaty clay over basalt	clayey-skeletal, mixed, nonacid, isohyperthermic	6b
		+ Typic	Namoa clay loam	fine, mixed nonacid, isohyperthermic	6
		+ Typic	Namoa peaty silt loam	loamy over sandy, calcareous, isohyperthermic	6a
Inceptisols	Tropaquepts	+ Typic	Vaigafa silty clay loam	fine, mixed, nonacid, isohyperthermic	13
		+ Typic	Lano silty clay loam and peaty clay loam	fine, silty, mixed, nonacid, isohyperthermic	14
		+ Typic	Palapala peaty loam	fine, ferritic, acid, isothermic	16
	Humitropepts	o Andic	Ma'asina stony clay	medial-skeletal, oxidic, isohyperthermic	12
		* Andic	Ma'asina stony and bouldery clay	medial-skeletal, oxidic, isohyperthermic	12a
		o Andic	Ma'asina very bouldery clay	medial over fragmental, oxidic, isohyperthermic	12b
		* Andic	Ma'asina hill soils	medial-skeletal, oxidic, isohyperthermic	12H
		o Andic	Aleisa very stony silty clay loam	medial-skeletal, oxidic, isohyperthermic	47
		o Andic	Aleisa very bouldery silty clay loam	medial over fragmental, oxidic, isohyperthermic	47a
		* Andic	Aleisa hill soils	medial-skeletal, oxidic, isohyperthermic	47H
		* Andic	Fagaga stony silty clay loam	medial-skeletal, oxidic, isohyperthermic	65a
		* Andic	Fagaga very stony silty clay loam	medial-skeletal, oxidic, isohyperthermic	65b
		* Andic	Fagaga hill soils	medial-skeletal, oxidic, isohyperthermic	65H
		o Andic	Tiavi silty clay loam	medial-skeletal, oxidic, isothermic	85
		* Andic	Tiavi stony silty clay loam	medial-skeletal, oxidic, isothermic	85a
		o Andic	Tiavi stony and bouldery silty clay loam	medial-skeletal, oxidic, isothermic	85b
		* Andic	Tiavi hill soils	medial-skeletal, oxidic, isothermic	85H
		o Fluventic (Andic)	Vaiola silty clay loam and gravelly loam	fine, oxidic, isohyperthermic	10
		+ Fluventic	Falevao silty clay loam	fine, oxidic, isohyperthermic	11
		+ Fluventic	Falevao slightly mottled silty clay loam	fine, oxidic, isohyperthermic	11a

Order	Great Group	Subgroup	Soil Name	Soil Family	Map Symbols
		* Lithic	A'ana shallow bouldery silty clay	clayey-skeletal, oxidic, isohyperthermic	29C
		+ Lithic	Aleipata steepland soils, very steep phase	clayey-skeletal, oxidic, isohyperthermic	63V
		* Oxic	A'ana hill soils	clayey-skeletal, oxidic, isohyperthermic	29H
		* Oxic	A'ana very stony silty clay loam	clayey-skeletal, oxidic, isohyperthermic	29a
		* Oxic	A'ana bouldery silty clay	clayey-skeletal, oxidic, isohyperthermic	29b
		o Oxic	A'ana stony silty clay	fine, oxidic, isohyperthermic	29
		o Oxic	Vailele stony silty clay loam	fine, oxidic, isohyperthermic	31
		o Oxic	Moamoa stony clay	clayey-skeletal, oxidic, isohyperthermic	32
		o Oxic	Asoleilei stony silt loam	clayey-skeletal, gibbsitic, isohyperthermic	37
		* Oxic	Asoleilei hill soils	clayey-skeletal, gibbsitic, isohyperthermic	37H
		o Oxic	Tafatafa very stony silty clay loam	fine, oxidic, isohyperthermic	46
		* Oxic	Tafatafa bouldery silty clay loam	clayey-skeletal, oxidic, isohyperthermic	46a
		* Oxic	Tafatafa very bouldery silty clay loam	clayey-skeletal, oxidic, isohyperthermic, also Lithic subgroups	46b
		* Oxic	Tafatafa hill soils	clayey-skeletal, oxidic, isohyperthermic	46H
		o Oxic	Avele stony silty clay loam	clayey over loamy-skeletal, gibbsitic, isohyperthermic	59
		* Oxic	Avele very stony silty clay loam	clayey-skeletal, gibbsitic, isohyperthermic	59a
		* Oxic	Avele bouldery silty clay loam	clayey-skeletal, gibbsitic, isohyperthermic	59b
		* Oxic	Avele hill soils	clayey-skeletal, gibbsitic, isohyperthermic	59H
		o Oxic	Solosolo silty clay loam	fine, gibbsitic, isohyperthermic	60
		* Oxic	Solosolo stony and bouldery clay	clayey-skeletal, gibbsitic, isohyperthermic	60a
		o Oxic	Etemuli silty clay loam	fine, gibbsitic, isohyperthermic	62
		* Oxic	Etemuli very stony silty clay loam	clayey-skeletal, gibbsitic, isohyperthermic	62a
		* Oxic	Etemuli very bouldery silty clay loam	clayey-skeletal, gibbsitic, isohyperthermic	62b
		* Oxic	Etemuli hill soils	clayey-skeletal, gibbsitic, isohyperthermic	62H
		+ Oxic	Aleipata hill soils	loamy-skeletal, oxidic, isohyperthermic	63H
		+ Oxic	Aleipata steepland soils	clayey-skeletal, oxidic, isohyperthermic	63S
		* Oxic	Falealili silty clay loam	fine, oxidic, isohyperthermic	64
		o Oxic	Falealili stony silty clay loam	clayey-skeletal, oxidic, isohyperthermic	64a
		* Oxic	Falealili very stony silty clay loam	clayey-skeletal, oxidic, isohyperthermic	64b
		* Oxic	Falealili hill soils	clayey-skeletal, oxidic, isohyperthermic	64H
		o Oxic	Afiamalu silt loam	clayey-skeletal, gibbsitic, isothermic	83
		* Oxic	Afiamalu hill soils	clayey-skeletal, gibbsitic, isothermic	83H
		o Typic	Papauta silty clay	fine, oxidic, isohyperthermic	58
		o Oxic	Papauta stony silty clay	clayey-skeletal, oxidic, isohyperthermic	58a
		* Typic	Papauta bouldery silty clay	clayey-skeletal, oxidic, isohyperthermic	58b
		* Typic	Papauta hill soils	clayey-skeletal, oxidic, isohyperthermic	58H
Inceptisols	Eutropepts	* Lithic	Nu'utele steepland soils, very steep phase	fine loamy, smectitic, isohyperthermic	51V
		* Typic	Vini clay	fine, smectitic, isohyperthermic	50
		* Typic	Vini hill soils	fine, smectitic, isohyperthermic	50H
		* Typic	Nu'utele hill soils	fine, smectitic, isohyperthermic	51H
		o Typic	Nu'utele steepland soils	fine, smectitic, isohyperthermic	51S
		o Typic	Mulimauga hill soils	fine, oxidic, isohyperthermic	54H
		* Typic	Mulimauga steepland soils	clayey over sandy-skeletal, oxidic, isohyperthermic	54S
		* Typic	Olomauga stony silty clay	fine, oxidic, isohyperthermic	55
		+ Typic	Olomauga hill soils	clayey-skeletal, oxidic, isohyperthermic	55H
	Dystropepts	+ Andic	Salailua very stony silty clay loam	medial-skeletal, oxidic, isohyperthermic	48
		+ Andic	Salailua bouldery silty clay	medial-skeletal, oxidic, isohyperthermic	48a
		+ Andic	Salailua hill soils	medial-skeletal, oxidic,	48H

Order	Great Group	Subgroup	Soil Name	Soil Family	Map Symbols
				isohyperthermic	
		+ Andic	Lata hill soils	medial-skeletal, oxidic, isohyperthermic	71H
		+ Andic	Lata steepland soils	medial-skeletal, oxidic, isohyperthermic	71S
		+ Lithic	Lata steepland soils, very steep phase	fine-skeletal, oxidic, isohyperthermic	71V
		o Oxic	Saleimoa very stony silty clay loam	coarse loamy, gibbsitic, isohyperthermic	25
		* Oxic	Saleimoa very bouldery silty clay loam	clayey-skeletal, gibbsitic, isohyperthermic	25a
		* Oxic	Saleimoa hill soils	clayey-skeletal, gibbsitic, isohyperthermic	25H
		o Oxic	Sauaga clay	fine, halloysitic, isohyperthermic	67
		* Oxic	Sauaga hill soils	clayey-skeletal, halloysitic, isohyperthermic	67H
		+ Oxic	Uafato silty clay	fine, mixed, isohyperthermic	72
		+ Oxic	Uafato hill soils	fine, mixed, isohyperthermic	72H
		o Typic	Ufuiva very bouldery silt loam	loamy-skeletal, oxidic, isohyperthermic	36
		* Typic	Ufuiva hill soils	loamy-skeletal, oxidic, isohyperthermic	36H
		+ Typic	Salani hill soils	fine, gibbsitic, isohyperthermic	61H
		+ Typic	Salani steepland soils isohyperthermic	clayey-skeletal, gibbsitic,	61S
		+ Typic	Salani steepland soils, very steep phase	clayey-skeletal, gibbsitic, isohyperthermic	61V
Entisols	Sulfaquents	+ Typic	Loga sandy clay	fine, mixed, nonacid, isohyperthermic	1
		+ Typic	Loga peaty sand	fine, mixed, nonacid, isohyperthermic	1a
	Tropopsamments	+ Aquic	Mutiatele mottled sand	carbonatic, isohyperthermic	4
		+ Aquic	Mutiatele peaty loamy sand and sandy peat	carbonatic, isohyperthermic	4a
		+ Lithic	Fusi shallow grey sand over basalt	carbonatic, isohyperthermic	3a
		+ Typic	Lufi sand	mixed, isohyperthermic	2
		+ Typic	Lufi gravelly sand	mixed, isohyperthermic	2a
		+ Typic	Fusi sand	carbonatic, isohyperthermic	3
		+ Typic	Fusi stony and bouldery sand and stony clay	carbonatic, isohyperthermic	2b
	Troporthents	+ Lithic	Matavanu sandy and fine gravel	fragmental, mixed, nonacid, isohyperthermic	17
		+ Lithic	Matavanu stony gravel	fragmental, mixed, nonacid, isohyperthermic	17a
		+ Lithic	Matavanu hill soils	fragmental, mixed, nonacid, isohyperthermic	17H

o classification derived from full soil analyses and soil profile descriptions.

* classification derived from interpretation of full analyses of a member of the same series, soil profile description and limited soil analyses.

+ classification derived from interpretation of full analyses of soils of similar series, soil profile descriptions and limited analyses.

† Note the term 'amorphic' is yet to be approved as a family differentia, although included in Leamy *et al.* 1988. Classification of the Andisols in this survey following current family criteria simply involves deletion of 'amorphic'.

APPENDIX 4: SOILS CLASSIFIED ACCORDING TO THE F.A.O. CLASSIFICATION

Soil series	Map symbols	Soil units
Lalovi	7	Fibric Histosol
Latalua	8	Fibric Histosol
Man Made soils	15	Umbric Anthrosol
Fusi	3a	Eutric Leptosol
Namoa	6a	Eutric Leptosol
Matavanu	17, 17a, 17H	Dystric Leptosol
Mu	74, 74H	Dystric Leptosol
Mataoleafi	73, 73a, 73H	Dystric Leptosol
Aopo	18, 18H	Mollic Leptosol
Faleolupo	19, 19a	Mollic Leptosol
Pulea	20	Mollic Leptosol
Sataua	24, 24a, 24H	Mollic Leptosol
Loga	1, 1a	Thionic Fluvisol
Apia	5	Mollic Fluvisol
Sauniatu	9, 9a	Mollic Fluvisol
Fusi	3, 3b	Calcaric Fluvisol
Falevao	11, 11a	Umbric Fluvisol
Vaiola	10	Dystric Fluvisol
Lufi	2, 2a	Eutric Fluvisol
Mutiatele	4, 4a	Calcic Gleysol
Namoa	6, 6a	Calcic Gleysol
Palapala	16	Dystric Gleysol
Vaigafa	13	Eutric Gleysol
Lano	14	Eutric Gleysol
Vaisala	23, 23H	Mollic Andosol
Neiafu	26H, 26S	Mollic Andosol
Mulifanua	27H, 27S, 27V	Mollic Andosol
Olomanu	30H, 30S	Mollic Andosol
Togitogiga	35, 35a, 35H	Mollic Andosol
Lefaga	40, 40a, 40H	Mollic Andosol
Tanumalala	41, 41a, 41b, 41H	Mollic Andosol
Atua	42, 42H	Mollic Andosol
Olo	43H, 43S	Mollic Andosol
Fa'amasa	44H, 44S, 44V	Mollic Andosol
Tapuele	45	Mollic Andosol
Tafua	52, 52H	Mollic Andosol
Folu	53S	Mollic Andosol
Upolu	69H, 69S, 69V	Mollic Andosol
Maugamoa	75, 75H	Mollic Andosol
Mafane	76S	Mollic Andosol
Magia	28, 28a	Umbric Andosol
Puna	38, 38H	Umbric Andosol

Soil series	Map symbols	Soil units
Samoa	77	Umbric Andosol
Savai'i	78S	Umbric Andosol
Salega	79, 79H	Umbric Andosol
Elitoga	80H, 80S	Umbric Andosol
Sili	81	Umbric Andosol
Maugasili	82H, 82S	Umbric Andosol
Lanuto'o	84H, 84S, 84V	Umbric Andosol
Mata'ana	86S	Umbric Andosol
Tanutala	39H, 39S	Haplic Andosol
Gaegae	49, 49a, 49H	Haplic Andosol
Fagapolo	56	Haplic Andosol
Tiotala	57H, 57S, 57V	Haplic Andosol
Alataua	22H, 22S	Vitric Andosol
Papaloa	66H, 66S, 66V	Umbric Ferralsol
Tuave	70, 70H	Umbric Ferralsol
Fagaga	65	Akric Ferralsol
Luatuanu'u	68, 68a, 68H	Akric Ferralsol
Vaipouli	33	Haplic Ferralsol
Papauta	58, 58a, 58b, 58H	Umbric Cambisol
Solosolo	60, 60a	Umbric Cambisol
Sauaga	67, 67H	Umbric Cambisol
Tiavi	85, 85a, 85b, 85H	Umbric Cambisol
A'ana	29, 29a, 29b, 29C, 29H	Ferralic Cambisol
Vailele	31	Ferralic Cambisol
Moamoa	32	Ferralic Cambisol
Asoleilei	37, 37H	Ferralic Cambisol
Tafatafa	46, 46a, 46b, 46H	Ferralic Cambisol
Salani	61H, 61S, 61V	Ferralic Cambisol
Falealili	64, 64a, 64b, 64H	Ferralic Cambisol
Lata	71H, 71S, 71V	Ferralic Cambisol
Uafato	72, 72H	Ferralic Cambisol
Afiamalu	83, 83H	Ferralic Cambisol
Saleimoa	25, 25a, 25H	Dystric Cambisol
Saleilua	48, 48a, 48H	Dystric Cambisol
Avele	59, 59a, 59b, 59H	Dystric Cambisol
Atemuli	62, 62a, 62b, 62H	Dystric Cambisol
Aleipata	63H, 63S, 63V	Dystric Cambisol
Fagaga	65a, 65b, 65H	Dystric Cambisol
Afuiva	36, 36H	Chromic Cambisol
Ma'asina	12, 12a, 12b, 12H	Eutric Cambisol
Vaipapa	34H, 34S	Eutric Cambisol
Nu'utele	51H, 51S, 51V	Eutric Cambisol
Vini	50, 50H	Eutric Cambisol
Mulimaauga	54H, 54S	Eutric Cambisol
Olomauga	55, 55H	Eutric Cambisol

APPENDIX 5: COMPARISON OF EQUIVALENT SOIL SERIES OF WESTERN SAMOA AND AMERICAN SAMOA

WESTERN SAMOA		AMERICAN SAMOA		
Soil series	Soil Taxonomy	Soil series	Soil Taxonomy	Parent materials of American Samoan soils USDA (1984)
Ma'asina	Andic Humitropept	Aua	Typic Hapludoll	colluvium
Vaipapa	Lithic Hapludoll	Fagasa	Typic (and Lithic) Hapludoll	basalt
Sataua	Lithic Fulvudand (Lithic Dystrandept)	Iliili	Lithic Dystrandept	volcanic ash on pahoehoe lava
Namoa	Aquic Tropopsamment	Insak	Typic Tropaquent	coral sand and organic matter
Apia	Cumulic Hapludoll	Leafu	Cumulic Hapludoll	alluvium
Lalovi	Hydric Tropofibrist	Mesei Variant	Sapric Tropofibrist	organic residues
Fusi	Typic Tropopsamment	Ngedebus Variant	Typic Troporthent	coral sand
Loga	Typic Sulfaquent	Ngerungor Variant	Typic Tropohemist	estuarine organic material
Sasina	Andic Hapludoll (Typic Hapludoll)	Ofu	Typic Hapludoll	volcanic ash and basalt
Fa'amasa) Olo)	Eutric Fulvudand (Typic Hapludoll)	Oloava	Typic Dystrandept	volcanic ash and cinders
Tanutala	Hydric Hapludand	Olotania	Typic Hydrandept	volcanic ash and cinders
Tapuele	Typic Hapludand (Typic Dystrandept)	Pavaiai	Typic Dystrandept	volcanic ash and aa on pahoehoe lava
Nu'utele	Typic Eutropept	Puapua	Lithic Eutrandept	andesitic tuff
Tafua	Eutric Hapludand (Udic Eutrandept)	Sogi	Udic Eutrandept	volcanic ash on tuff
Tiavi	Andic Humitropept	Sogi Variant	Typic Hapludoll	volcanic ash over pahoehoe lava
Palapala	Typic Tropaquent	Tafuna	Typic Tropofolist	organic matter over fragmental aa lava

APPENDIX 6: LAND CAPABILITY

CLASS 1: Land with few limitations to agricultural use.

CLASS 1a: Flat to undulating, imperfectly to well drained land without moisture deficit. Soils have high to medium natural nutrient levels and less than 5% stones.
(5, 6, 9, 9a, 10, 11, 11a)

IMPROVEMENTS NEEDED:
Artificial drainage (5, 6, 10)
Flood protection (9, 10, 11)
N, P, K fertilisers depending on crop
Blockshading (shelterbelts)

CROPS:
Coffee, taro, ta'amu, cassava, yam, sweet potato, black pepper, coconut, breadfruit, Tahitian lime, banana, avocado, cabbage (chinese), pasture, forest nurseries (9, 10, 11)

CLASS 1b: Flat to rolling well to somewhat excessively drained land without moisture deficit. Soils have low natural nutrient levels, up to 25% stones and in some cases slight erosion occurs under cultivation.
(9b, 38, 45, 52, 55, 56, 58, 58a, 59, 60, 62, 64, 65, 65a, 67, 68)

IMPROVEMENTS NEEDED:
N,P,K fertilisers (45, 56, 58, 58a, 59, 60, 62, 64, 67)
N,P,K fertilisers and P depending on crop (52, 55)
N,P,K fertilisers and lime*, Mg depending on crop (38, 65, 65a, 68)
Improved access (68)
Block shading (shelterbelts)

CROPS:
Coconut, coffee, Ava (Yagonda), taro, cassava, yam, sweet potato, black pepper, breadfruit, citrus, banana, pawpaw, avocado, ginger, pasture, forest nurseries

CLASS 1c: Flat to rolling well drained land without or with less than 30 days moisture deficit. Soils have low to medium natural nutrient levels and up to 50% stones at the surface.
(12, 12a, 33, 37, 41)

IMPROVEMENTS NEEDED:
N,P,K fertilisers and lime*, Mg depending on crop.
Irrigation
Blockshading (shelterbelts)

CROPS:
Coconut, coffee, Ava (Yagona), ginger, taro, ta'amu, cassava, sweet potato, black pepper, breadfruit, cocoa, citrus, banana, pawpaw, avocado, mango, guava, tomato
pasture (33, 37) if water available

CLASS 2: Land with moderate limitations to agricultural use and few limitations to forestry.

CLASS 2a: Flat to rolling well drained land without moisture deficit. Soils have low to medium natural nutrient levels and more than 50% stones and/or boulders at the surface.
(12b, 40, 40a, 41a, 41b, 42, 46, 46a, 46b, 47, 47a, 48, 48a, 49, 49a, 58b, 59a, 59b, 60a, 62a, 62b, 64a, 64b, 65b)

IMPROVEMENTS NEEDED:
N,P,K fertilisers depending on crop
Block shading (shelterbelts)

CROPS:
Coffee, taro, cassava, yam, black pepper, coconut (to 1000 feet altitude), breadfruit (to 700 feet altitude), citrus, banana, pawpaw, avocado, commercial forestry

CLASS 2b: Flat to rolling well drained land with more than or less than 30 days moisture deficit. Natural nutrient levels vary from high to low and up to 50% stones and/or boulders at the surface.
(21, 24, 24a, 25, 28, 28a, 29, 29a, 29b, 31, 32, 50)

IMPROVEMENTS NEEDED:
N,P,K fertilisers depending on crop (21, 24, 24a, 25, 28, 28a, 29, 29a, 29b)
N and P, K fertilisers depending on crop (31, 32, 50)
Irrigation
Blockshading (shelterbelts)

CROPS:
Ta'amu, coconut, cocoa, pineapple, ginger, mango, guava, coffee, sweet potato (31, 32)

CLASS 2c: Hilly well drained land without moisture deficit. Soils have low to medium natural nutrient levels and more than 50% stones or boulders at the surface. Slight erosion occurs under cultivation.
(37H, 38H, 40H, 42H, 44H, 46H, 47H, 48H, 54H, 55H, 57H, 58H, 59H, 62H, 65H, 67H, 72H)

IMPROVEMENTS NEEDED:
Contour planting to prevent erosion
N,P,K fertilisers (less fertiliser on 54H) (Mg possibly required 37H)
Block shading (shelter belts) for coffee

CROPS:
Banana, cassava, coconut (to 1000 feet altitude), coffee, taro, pawpaw
pasture (44H, 57H, 62H, 72H)
citrus (44H, 54H, 57H, 62H, 65H)

CLASS 2d: Hilly well drained land with more than or less than 30 days moisture deficit. Soils have high to medium natural nutrient levels and up to 50% stones or more and/or boulders at the surface. Slight erosion occurs under cultivation.
(21H, 24H, 27H, 29H, 50H)

IMPROVEMENTS NEEDED:
Contour planting to prevent erosion
P fertilisers and K depending on crop

CROPS:
Coconut, banana, breadfruit, cassava, ta'amu, mango, guava, cocoa, citrus, forestry (24H)

CLASS 2e: Flat poorly to imperfectly drained land. Soils have low natural nutrient levels and need artificial drainage to become productive. Salt spray occurs on soils 4 and 4a.
(4, 4a, 6a, 6b)

IMPROVEMENTS NEEDED:
Block shading (shelterbelts) against salt spray (4, 4a)

CROPS:
Guava, coconut, pulaka, pandanus, sago (6, 6a)

CLASS 2f: Flat to rolling well drained uplands without moisture deficit. Soils have low natural nutrient levels and erosion could occur under cultivation.
(70, 72, 83, 85, 85a, 85b)

IMPROVEMENTS NEEDED:
Improved access
N,P,K fertilisers

CROPS:
Citrus, pasture, forestry
Forestry only on 85a

CLASS 3: Land with severe limitations to agricultural use and moderate to severe limitations to forestry.

CLASS 3a: Flat to rolling excessively to well drained land. Soil textures vary from sand to silty clay loam, and in places the soils are stony with rooting volume to 40 cm.
(2, 2a, 3, 3a, 3b, 25a)

IMPROVEMENTS NEEDED:
Mulching

CROPS:
Coconut, pandanus, breadfruit

CLASS 3b: Hilly and steepland, well drained without moisture deficit. Soils often have more than 50% stones and boulders and have a moderate to severe erosion potential.
(12H, 35H, 36H, 39H, 39S, 41H, 49H, 52H, 61H, 63H, 66H, 68H, 69H, 70H, 71H, 83H, 84H)

IMPROVEMENTS NEEDED:
Contour planting to prevent erosion
Conservation planting on eroded areas
N, P, K fertilisers (K needed for bananas) (52H has high bases)

CROPS:

Commercial forestry and conservation forestry, coconut (below 1000 feet), banana

CLASS 3c: Hilly and steepland, well drained with a moisture deficit of more or less than 30 days. Soils have more than 50% stones and boulders and have a moderate erosion potential.
(22H, 23H, 25H, 26H, 27S, 30H, 34H, 51H)

IMPROVEMENTS NEEDED:

Contour planting to prevent erosion
Conservation planting on eroded areas
N, P, K fertilisers depending on crop (51H has high bases)

CROPS:

Commercial forestry and conservation forestry
coconut, ta'amu (on slopes less than 25 degrees), breadfruit

CLASS 3d: Undulating to strongly rolling somewhat excessively to well drained land with moisture deficit of 30 days or more. Soils have more than 50% stones and boulders and pahoehoe lava sheets are close to the surface reducing rooting volume to 20 or 40 cm.
(19, 20, 23, 29c)

IMPROVEMENTS NEEDED:

K fertilisers (P, N depending on crop)

CROPS:

Ta'amu, coconut, conservation forestry

CLASS 3e: Flat to hilly moderately to well drained foothills and uplands (to 4000 feet elevation). Soils are very strongly leached and present access is difficult. Moderate to severe erosion potential for 75, 75H, 77, 79, 79H, 80H and 81.
(23, 36, 68a, 75, 75H, 77, 79, 79H, 80H, 81)

IMPROVEMENTS NEEDED:

None economic

CROPS:

Conservation forestry
Commercial forestry with selected species

CLASS 3f: Flat to undulating poorly drained land of bogs and depressions. Soils are acid peats with high ground water tables caused by pahoehoe lava sheets close to the surface.
(7, 8, 13, 14)

IMPROVEMENTS NEEDED:

Artificial drainage

CROPS:

Pasture

CLASS 4: Land unsuitable for agriculture or forestry.

CLASS 4a: Steep, very steep and hilly land with severe actual or potential erosion. Soils are rocky, or have more than 50% stones and boulders.
(22S, 26S, 27V, 30S, 34S, 43H, 43S, 43V, 44S, 44V, 51S, 51V, 53S, 54S, 57S, 57V, 61S, 61V, 63S, 63V, 66S, 66V, 69S, 69V, 71S, 71V, 76S, 78S, 80S, 82H, 82S, 84S, 84V, 85H, 86S)

IMPROVEMENTS NEEDED:
Conservation forestry

CROPS:
Nil

CLASS 4b: Flat to rolling and hilly land. Soils have pahoehoe lava sheets, boulders and stones close to the surface reducing rooting volume to less than 20 cm.
(17, 17a, 17H, 18, 18H, 19a, 35, 35a, 73, 73a, 73H, 74, 74H)

IMPROVEMENTS NEEDED:
None economic

CROPS:
Nil, (reserves, recreation)

CLASS 4c: Flat land of bogs and upland depressions. Soils have ground water at the surface for most of the year and present access is difficult.
(16)

IMPROVEMENTS NEEDED:
Nil (drainage if economic)

CROPS:
Nil (reserves, recreation, pasture if drained)

CLASS 4d: Flat land of estuarine bogs. Soils are saline and under tidal influence.
(1, 1a)

IMPROVEMENTS NEEDED:
Nil (recreation)

CROPS:
Nil

*Note: Lime on Oxisols and soils with oxidic, gibbsitic, kaolinitic mineralogy can induce deficiencies of micronutrients.

APPENDIX 7: SLOPE CLASS, SOIL DEPTH, SOIL TEXTURE. DRAINAGE CLASS, TOLERANCES DURING GROWTH, DROUGHT TOLERANCES, pH, FERTILISER AND CLIMATE REQUIREMENTS FOR SOME CROPS GROWN IN THE PACIFIC REGION

SLOPE CLASS

CROP	<1°	1-5°	6-10°	> 10° (N-facing)	> 10° (S-facing)
Coffee Arabica	8	8	6	4	4
Robusta	8	8	6	4	4
Ava (Yaqona)					
Pineapple	8	4	4	4	4
Ginger	4	4	6	4	2
Taro	8	8	6	4	4
Giant Taro	8	8	6	4	4
Cassava 8	8	8	4	4	
Yams	8	6	4	2	2
Sweet Potato	8	6	4	4	2
Passionfruit	8	8	8	8?	8?
Black Pepper	8	8	8	4	4
Vanilla	8	8	6	4	4
Coconut 8	8	8	8	8	
Breadfruit	8	6 (8)?	6	4	2
Cocoa	8	8	6	4	4
Tahitian lime	8	8	8	8	8
Banana 8	8	?(8) (6)?	6	2	
Pawpaw 8	8	8	8?	8?	
Avocado	4	6	6	4	4
Mangos 8	8	6	4	2	
Guava	8	8	8	6	4
Carrot	8	8	6	4	4
Cabbage (Chinese)	8	6	4	2	2
Tomato 8	6	4	2	2	
Cucumber	8	8	6	4	4
Lettuce 8	6	4	4	4	
Common Bean	8	8	6	4	4
Soy Beans	8	8	4	4	2
Winged bean	8?	8?	4	4	2?

Class:

2 = generally unsuitable for production
4 = production is practicable only with special (e.g. benching) measures
6 = production is usually practicable without special measures
8 = favourable for most methods of production

SOIL DEPTH

CROP		< 10 cm	10-20 cm	21-40 cm	> 40 cm	
Coffee	Arabica	2	2	4	8	
	Robusta	2	2-4	4-6	8	
Ava (Yaqona)						
Pineapple		2	2	4	6	
Ginger		2	4	6	8	
Taro		2	4	6	8	
Giant Taro		2	4	6	8	
Cassava 2		2	4	8		
Yams		2	4	6	8	
Sweet Potato		2	4	8	8	
Passionfruit		2	4	6	8	
Black Pepper		2	4	8	8	
Vanilla		2	4	6	8	
Coconut 2		2	2	8		
Breadfruit		2	4	6	8	
Cocoa		2	2	4	6	Opt. > 1.5 m (tap root)
Tahitian lime		4	6	8	8	
Banana		2	4	6	8	
Pawpaw		4	6	8	8	
Avocado		2	2	2	6	> 90 cm (Class 8)
Mangos		2	2	4	8	
Guava		2	4	6	8	
Carrot		2	4	6	8	
Cabbage (Chinese)		2	6	8	8	
Tomato		4	6	8	8	
Cucumber		4	6	8	8	
Lettuce		4	6	8	8	
Common Bean		4	6	8	8	
Soy Beans		4	6	8	8	
Winged bean		2	4	8	8	

Class:

2 = generally unsuitable for production
4 = production is only practicable with special (e.g. mounding) measures
6 = production is usually practicable without special measures
8 = favourable for most methods of production

SOIL TEXTURE

CROP	Uniform sand	Uniform loam	Sand over clay	Loam over clay	Rocky Soils	No soil root medium
Coffee Arabica	4	8	4	4	2	2
Robusta	4	8	4-6	6	2	2
Ava (Yaqona)						
Pineapple	6	8	?	?	2	2
Ginger	4	8	6	4	2	2
Taro	8	8	8	6	2	2
Giant Taro	6	8	6	6	4	2
Cassava	8	8	4	4	2	2
Yams	4	8	4	4	2	2
Sweet Potato	2	8	4	4	2	2
Passionfruit	6	6	4	4	4	2
Black Pepper	2	8	4	6	2	2
Vanilla	4	8	4	6	2	2
Coconut	8	8	6	6	2	2
Breadfruit	2	8	4	4	4	2
Cocoa	4	8	4-6	6	2	2
Tahitian lime	8	8	6	6	4	2
Banana	2	8	4?	6	6?	2
Pawpaw	8?	8	6	6	4	2
Avocado	6	4	4	4	4	2
Mangos	8	8	4	4	2	2
Guava	8	8	8	6	4	2
Carrot	6	8	4	8	2	2
Cabbage (Chinese)	2	6	4	6	4	2
Tomato	4	8	6	6	4	2
Cucumber	8	8	6	8	2	2
Lettuce	4	8	4	8	2	2
Common Bean	2	8	2	6	2	2
Soy Beans	4	8	6	6	4	2
Winged bean	?	8	?	?	?	?
	low awc	high awc	low-med awc	med awc	v.Low awc	water/ hydroponics

Class:

2 = generally unsuitable for production
4 = production is only practicable with special (e.g. mulching and ripping) measures
6 = production is usually practicable without special measures
8 = favourable for most methods of production

CROP		DRAINAGE CLASS Fast (well or better)	Imperfect	Very Slow (Poor)
Coffee	Arabica	8	4	2
	Robusta	8	4	2
Ava (Yaqona)				
Pineapple		8	4	2
Ginger		8	4	2
Taro		8	6	4
Giant Taro		8	6	6 (some cultivars)
Cassava		8	4	2
Yams		8	4	2
Sweet Potato		8	4	2
Passionfruit		8	4	2
Black Pepper		6	4	2
Vanilla		8	4	2
Coconut		8	4	2
Breadfruit		8	4	4
Cocoa		8	4	2
Tahitian lime		8	4	2
Banana		8	4	2
Pawpaw		8	4	2
Avocado		8	4	2
Mangos		8	4	2
Guava		8	6	4
Carrot		8	4	2
Cabbage (Chinese)		8	4	2
Tomato		8	4	2
Cucumber		8	6	2
Lettuce		8	6	2
Common Bean		6	4	2
Soy Beans		8	6	4
Winged bean		8	?	?

Class:

2 = generally unsuitable for production
4 = production is practicable only with special (e.g. drainage) measures
6 = production is usually practicable without special measures
8 = favourable for most methods of production

TOLERANCES DURING GROWTH

CROP		Flooding	Salt Spray	Norms Salt in root zone	Shade	Wind*
Coffee	Arabica	2	2	2	2	3
	Robusta	2	2	2	2	3
Ava (Yaqona)						
Pineapple		2	2		1	5
Ginger		4?	2	3	3	7
Taro		2		4	1	5
Giant Taro		5?	2	3		3
Cassava		2?		2		7
Yams		2			1	3-5?
Sweet Potato		2	2	2	1	7
Passionfruit		2			3?	5
Black Pepper		2		2	1	7
Vanilla		2			3	3
Coconut		5	4	6	1	5
Breadfruit		6	2	4	1	5
Cocoa		2	2	2	2	3
Tahitian lime		2	4	4	1	5
Banana		3	3	4	2	3
Pawpaw		2	2	2	1	3
Avocado		2	2	2	4	3
Mangos		6?		4	2	3
Guava		7?	6	6	1	3
Carrot		3	2	2	1	7
Cabbage (Chinese)		3	2	2	1	3
Tomato		2	2	2	2	3
Cucumber		2	2	2	1	7
Lettuce		3	2	2	1	7
Common Bean		3	2	2	3	3
Soy Beans		3	3	4	2	5
Winged bean		4	?	?	1	3

Class: flooding

2 = intolerant of standing water
3 = can stand water logging 1-2 days
4 = can stand water logging 3-4 days
5 = can stand water logging 1-2 weeks
6 = can stand water logging 2-4 weeks
7 = can stand water logging > 4 weeks

Salt Spray/Salt in root Zone

2 = intolerant
4 = not required, some tolerance
6 = not required high tolerance
8 = beneficial

Shade 1 = full light essential for commercial production
5 = tolerate deep continuous shade

Wind 3 = Extremely harmful
5 = moderately harmful
7 = Negligible effect on production

* Wind: (Effect of wind 80-100 km/hr for 12 hours at most sensitive growth stage

DROUGHT TOLERANCE* - f(varieties)

	VARIETAL RANGE				
CROP	Lowest	Norm	Water requirement mm/ growing period	Highest	Drought requirement
Coffee Arabica		4-5?			3
Robusta		4-5?			
Ava (Yaqona)					
Pineapple		8	700-1000		7
Ginger		7			7
Taro	3	5		8	3
Giant Taro		5	?		3
Cassava		7			3
Yams		4		8	3
Sweet Potato		7			3
Passionfruit		4			3
Black Pepper		7	600-900 mm		3
Vanilla		4			3
Coconut	8	8		8	3
Breadfruit	6	7		8	3
Cocoa		4-5			3
Tahitian lime		6	900-1200 mm		3
Banana	4	5			
			1200-2200 mm	7	3
Pawpaw		5			3
Avocado		7			3
Mangos		8			7
Guava		8			7
Carrot		4			3
Cabbage (Chinese)		5			3
Tomato	5	6	400-600 mm	7	3
Cucumber		4			3
Lettuce		3			3
Common Bean	5	6		7	5
Soy Beans	5	6		7	7
Winged bean	5	6		7	7

Class:

1 = Crop is, or would have to be, grown in standing or running water without solid root medium.
2 = Crop is, or would have to be grown in solid root medium with free water continuously around roots.
3 = Irrigation or rainfall needs to be every 1-2 days
4 = Irrigation or rainfall needs to be semi-weekly
5 = Irrigation or rainfall needs to be weekly
6 = Can survive 1-2 weeks without irrigation or rainfall
7 = Can survive 2-4 weeks without irrigation or rainfall
8 = Can survive 4-12 weeks without irrigation or rainfall

Drought requirement: Some growth stage i.e. when drought (stress) is beneficial
3. - No 5. - 7. Yes, definitely needs

		SOIL pH	
CROP	< 5.5	5.5-7.0	>7.0
Coffee Arabica	6	8 6 pt range	6
Robusta	6	8 5.5-7.0	6
Ava (Yaqona)	4?	8	4?
Pineapple	8	8 (smooth cayenne pH 5.5)	4
Ginger	4	8	2
Taro	?	8	8
Giant Taro		8	
Cassava	6	8	2
Yams	4	8	6
Sweet Potato	4	8	4
Passionfruit	4	6	4
Black Pepper	6	8	4
Vanilla	4	8	4
Coconut	6	8	6
Breadfruit	4	8 Opt. range 5.0-8.0	2
Cocoa	4	8 Opt. range 6.5	4
Tahitian lime	4	8 Opt. range 5-6.0	4
Banana	4	8 Opt. range 6-7.5	4
Pawpaw	4	8 Opt. range 6-7.0	6
Avocado 4	8	6	
Mangos	2	8	4
Guava	6	8	6
Carrot	4	8	4
Cabbage (Chinese)	4	8	4
Tomato	4	8	4
Cucumber	4	8	4
Lettuce	4	8	4
Common Bean	4	8 Opt. range 5.5-6.0	4
Soy Beans	4	8	6
Winged bean	2	8	6

Class:

2 = generally unsuitable for production
4 = production is practicable only with special (e.g. liming) measures
6 = production is usually practicable without special measures
8 = favourable for most methods of production

FERTILISER REQUIREMENTS

Crop	N kg/ha	Majors P kg/ha	Norms and Common rates K kg/ha	Ca	Mg	Minor
Coffee Arabica	7	5	7	5 ?	5	3 (B, Fe, Zn)
Robusta	5	5	5	4	4	
Ava (Yaqona)						
Pineapple	7 230-300	4 45-65	8 110-220	3	3	5 (Fe, Mn, Zn, B, Ca)
Ginger	7	5	6	4	3	5
Taro	5	5	5	4	4	2 (Fe)
Giant Taro						
Cassava	5	4	7			3 (Zn)
Yams	7	4	7		5?	
Sweet Potato	5 0.5-1.0 t/ha 6: 9:15 NPK	5	5			
Passionfruit	5	5	5	5	5	1
Black Pepper	7 100-170 kg N/ha	5 25-50 kg P/ha	7 50-100 kg K/ha	5	5	
Vanilla	5	5	5		5	2 (Fe)
Coconut	5	3	5	2	3	1
Breadfruit	4	4	4	2	2	1
Cocoa	5	5	5	3	4	3 (Fe, Zn)
Tahitian lime	6 Soil dependent 100-200 kg N/ha	4 35-45 kg P/ha	6 50-160 kg K/ha	6	6	3 (Fe, Zn)
Banana	6 200-400 kg N/ha	5 45-60 kg P/ha	7 240-480 kg K/ha	4	5	2 (Zn)
Pawpaw	7	7	7	6	6	2
Avocado	6	5	5	3	4	5 (Zn, Fe)
Mangos	6	3-4	6	5	3-4	2 (Zn)
Guava	7	5	7	5	5	5
Carrot						
Cabbage (Chinese)	7	5	5	4	3	3
Tomato	6 40-80 kg N/ha	6 30-90 kg P/ha	6 50-110 kg K/ha	4	4	4
Cucumber	5	7?	5			
Lettuce	7	7	7	7		3
Common Bean	5 20-40 kg N/ha	5 40-60 kg P/ha	3 50-120 kg K/ha	5	3	2 (Boron)
Soy Beans	4	5 30-60 kg P/ha	5 50-75 kg K/ha	3	3	2
Winged bean	3	5	5	3	3	1

5: N 100-150 kg N/ha	25-50 kg P/ha	50-100 kg K/ha
7: > 150 kg N/ha	> 50 kg P/ha	> 100 kg K/ha

CLASS:

MAJOR NUTRIENTS

3 = Levels in most soils are adequate for commercial production
5 = modest fertilizer applications are generally necessary
7 = high levels of fertiliser applications are generally necessary for commercial production

MINOR NUTRIENTS

1 = special applications are very rarely needed
5 = special applications are often needed

CLIMATE REQUIREMENTS

CROP	Optimal* Annual Rainfall (mm)	Humidity	Optimal temp. range (°C)	Optimal Elevation Range (m)	Latitude Range	Notes
Coffee Arabica	1500-2250	High	16-27	1000-2000	24S-24N	2 mo. dry period
Robusta	1000-2500	High	20-32	0-1600		
Ava (Yaqona)	1900-4000	High	25-27			
Pineapple	1000-1500	High	Smooth Cayenne 18-21 others 22-30		25° N+S	
Ginger	> 1500	High	19-28	0-1500		
Taro	> 2500	High or Low	25-30			
Giant Taro	700-4200	High or Low	15-29			
Cassava	500-5000	High	25-29	0-1600		
Yams	> 1500	High	25-30		20° N+S	
Sweet Potato	700-4000	High or Low	20-28	0-3000	40 N to 32S	
Passionfruit	700-2300	High	15-18	Uplands-purple var.		Yellow var. lowland hillslopes
Black Pepper	> 2500	High	20-22	0-500	20° N+S	
Vanilla	2000-2500	High	21-32	0-600		
Coconut	1200-2500	High	25-30	0-300	20° N+S	
Breadfruit	700-2500	High	17-33			
Cocoa	1000-2500	Low	18-31	0-350	20° N+S	
Tahitian lime	400-4100	High or Low	20-28	0-600		
Banana	2000-2500	High	22-27	0-750	30° N+S	
Pawpaw	700-4200	High	21-30	0-1600	32° N+S	
Avocado	300-4100	High	15-30			
Mangos	250-2500	Low	24-28	0-600		Need dry season
Guava	200-4200	Low	15-30	0-1600		
Carrot	300-4600	Low	3-27			
Cabbage (Chinese)	700-4100	High or Low	15-36			
Tomato	300-4600	Low	15-28	Mid elev. in Samoa		
Cucumber	700-4200	Low	20-30			
Lettuce	300-4100	Low	14-20	Upland		Best at hot, low elev.
Common Bean		High or Low	13-24	Mid elev.-upland		
Soybean	400-4100	Low	25-26	?	52N-52S	
Winged bean	?	Low	?	0-2000	20°N-10°S	

* Optimal ranges identified for some crops e.g. Coffee Arabica while others are ranges in which the crop will grow. For the latter, optimal range data was not available.

APPENDIX 8. ECONOMIC ASSESSMENT

This appendix presents an economic assessment of crop and forestry enterprises, cattle production and watershed protection. The first two are gross margin analyses; the last is an example involving unpriced values.

A8.1. GROSS MARGIN ANALYSIS OF CROP AND FORESTRY ENTERPRISES

The gross margin analysis has been undertaken to provide data for producers, advisors, planners and decision makers concerned with land use. This information is to supplement the technical and spatial information provided by the maps of soils, land use, tenure, topography and land capability. But more importantly the physical basis for the gross margin result should be determined from these technical factors of climate and soil etc that are aggregated into land capability.

The analyses were conducted for a wide range of crops and forestry enterprises. Because of lack of data and time, however, a number of the new enterprises being researched by the crop diversification programme of the Department of Agriculture, Forests and Fisheries (DAFF), were not able to be analysed.

High and low input options were considered in each crop type except for the fruit and vegetables group. These options were related the variety planted in the case of coconuts and cocoa, where the new high yielding options were used for the high input model. For coffee the "plantation" and "smallholder" options were differentiated by spacing and fertiliser application. In the case of bananas, the intended market, either export or the local green banana market, was the basis for deciding the expected high and low input packages respectively. It was intended that the agroforestry be the "smallholder" option to the "plantation" option based on the forest replanting programme of the Forestry Division. A number of agroforestry options are available, including fuelwood production and growing hardwood poles such as poumuli together with food crops taro, taamu and banana. The option chosen however was that being actively promoted as part of a pilot watershed protection scheme. This involves growing a leguminous shrub interplanted with a food crop in order to achieve continuous production.

Each enterprise was analysed financially and economically. The financial analysis is from the producers point of view and uses the costs and prices that they pay or receive. Therefore the costs and prices include all subsidies and taxes paid. Family labour is assumed to be unpaid. Instead a net return per labour day is provided as a measure of interest to a producer's decision to plant.

The economic analysis presents the costs and benefits to the nation. Taxes and subsidies are excluded as they are transfers from individuals to the Government or vice versa and do not represent a use of resources. The economic analyses provide the results that should guide land use planners in their advice to Government and in their developing of programmes and projects that will promote desirable options.

In developing advice using these results it is important to remember the limitations of the data on which they are based and not unnecessarily to constrain producers' own decisions. It is the producer who will face the costs and benefits of his/her decision and not their advisors.

A8.1.1 Technical Data for the Gross Margin Analysis

The DAFF Gross Margin publication (April 1988) was the starting point for the input and output assumptions. Further information was checked with technical sections of the DAFF crop and livestock divisions.

Coconuts

The Coconut Hybridization project provided yield data for the annual per acre production from the trial plantings of selected local tall palms and the hybrid Red Malayan Dwarf x Local Tall. The plot locations were at Afia plantation (WSTEC), Olomanu and Manase. The Afia plot receives standard plantation management with some initial fertilizer application and now some grazing by cattle. At Olomanu the regime was minimal maintenance and no fertilizer. Manase plot is maintained by the farmer and receives some fertilizer provided by DAFF. Data for later planting of the Red Malayan Dwarf x Rennel hybrid at Togitogiga was also provided. (see Table A8.1).

Table A8.1 *Coconut Yield Data: lb Copra per Acre*

Location:	Afia		Olomanu		Manase		Togitogig
Variety:	RLT	LT	RLT	LT	RLT	LT	RNL
Year							
5	554	9	253	0	380	0	651
6	1340	112	352	2	1283	15	2356
7	1894	484	1078	40	1833	308	2873
8	2094	788	990	70	2226	627	
9	2204	871	1267	218	1874	796	

Spacing 64 palms per acre

Cocoa

The Cocoa Agronomist provided data for the cocoa demonstration plots at Lefaga, Vaovai, Sataua, Aopo and Gatavai. Data estimated current levels of dry bean per acre production based on pod counts. Records for previous years were not available. Yields of Amelonado from a Nu'u trial were available for the 3rd to the 6th year. An early spacing, shade and variety trial at Asau with two years of records was also reviewed. The demonstration plot data represents potentially the most useful crop yield information for a range of sites under uniform management. This could be related to land capability rating provided the full record from planting can be relocated and written up.

Table A8.2 *Cocoa Yield Data: lb dry bean per acre*

Demonstration Plots			
Location	**Year Plant**	**Yield Year**	**Yield Est 1988**
Lefaga	1982	6	1394
Vaovai	1982	6	853
Sataua	1981	7	856
A'opo	1981	7	634
Gataivai	1983	5	749

Nu'u Amelonado Trial Planted 1979

Year	Yield
3	187
4	1234
5	2200
6	2100

Coffee

Full records for labour inputs for development, maintenance, harvesting and processing plus coffee production were provided from a private plantation coffee development at Vaia'ata. This was invaluable for producing the coffee gross margin. The DAFF coffee programme is underway and a series of demonstration plots similar to that set up for cocoa should be considered. The plot locations should follow where possible the range of land capability units on which coffee is recommended. Smallholder coffee yields were taken from a project proposal developed by DAFF in 1978.

Banana

DAFF is at present reconsidering a programme of export banana production. Yields in the DAFF gross margin publication were used and represent production levels obtained at Nu'u and Tanumalala with full input use. Local market, low input production assumptions were derived from the high input information and should be checked by farmer survey. Data by site under similar management is not available.

Fruit and Vegetables

The DAFF gross margin publication provided vegetable inputs and outputs based on information from Nafanua and Nu'u. A USP School of Agriculture survey of vegetable growers inputs and outputs was used to check the DAFF data. Passionfruit and mango data followed early 1980's project proposals from the Food Processing Laboratory. Development

Bank of Western Samoa papers reviewing farmer performance in passionfruit production were also valuable. Mango production is based on very limited investigatory plantings at Alafua and Asau and needs further work.

Taro and Agroforestry

The DAFF gross margin data was supplemented by the agroforestry trial data from Vailima. This agroforestry enterprise is potentially one of the most valuable developed in recent years both economically and for conservation of land and soil resources. Data for a range of land capability units would be desirable.

Forestry

Two forestry gross margins were developed as follows:

(a) a fifteen year production cycle for *Eucalyptus deglupta* based on line planting at 2 metres in rows 10 metres apart giving 200 stems per acre.

(b) a twenty-five year production cycle for Mahogany based on close planting at 2 metres in rows 5 metres apart giving 400 stems per acre.

Data came from several sources provided by the DAFF Forestry Division.

(a) Labour inputs for the silviculture operations for the two systems used labour day levels projected by Groome Poyry Ltd (1988).

(b) Transport and supervision costs followed Armitage, Bartle and Reti (1984) using 2.5 percent of the silviculture labour cost. It was put in as a separate item, however, to allow the forestry gross margins to conform with the crop financial and economic analyses. Labour costs are then able to be valued at their opportunity cost to the nation in the economic model but left unvalued in the financial analysis.

(c) Non silviculture inputs were derived from Groome Poyry Ltd (1988). Seedling costs used the project nursery operational and capital costs with a 30-year life for the latter, producing 900,000 seedlings per year. Tools and stores were shown separately but used the percentage relationship to land preparation labour cost established by Armitage, Bartle and Reti (1984). Also used were their fire protection costs adjusted to mid 1989 values using the CPI. The per metre road costs for arterial and compartment roads were from Groome, and assumed 10 metres per acre for a 250 acre development.

(d) The replanting project's fixed costs for housing workshops and administrative overheads were excluded from the gross margin analysis to be comparable with other enterprises. Land rental was excluded as the gross margin is used for comparing alternative land uses. Therefore including a land opportunity cost is not relevant to the comparison.

(e) Yield data from Revilla (1988) was checked against yield assumptions in Groome Poyry (1988). Sawlog production yields for a good site index (35) from Revilla's models for the selected production cycles, 15 and 25 years. These yields coincided well with the Groome yields at the assumed stocking rates.

A8.1.2 Product Prices and Input Costs for Enterprise Gross Margins

The World Bank "Half Yearly Revision of Commodity Price Forecasts" dated June 1989, has been used to project the returns for the main commodity products exported from Western Samoa.

Real prices are not expected to increase over current levels through to the year 2000. Over the same period nominal price in US dollars increases by 6 percent per year based on the long run expected decline in the US dollar.

Data on the exchange rate between the Tala and US dollars indicates parity has been maintained from 1985 at around US$0.45/tala. Therefore the medium term nominal US dollar price to 1995 is proposed to represent the medium term real price projection as at June 1989, for Western Samoan exports.

Coconut Product Prices

Coconut Oil

Year	**1988**	**1989**	**1990**	**1995**	**2000**
Real Price (1985 US $/t)	406	385	336	401	374
Nominal Price (US $/t)	565	550	535	790	915

Copra

Year	1988	1989	1990	1995	2000
Real Price (1985 US $/t)	286	259	270	287	266
Nominal Price (US $/t)	398	370	430	65	651

Price Assumptions for Coconut Production

Farmers are able to sell whole fresh nuts to a commercial processing plant making coconut food products, and to exporters of fresh nuts. The Copra Board has regulated the price for the sale of whole nuts but is examining a recommendation to allow the price to be set by private negotiation. This is a higher value end use for an increasing volume of coconut production.

However, projections are based on copra production as the main end use of coconut production at present.

Relationship Between the Projected CIF Price and Price to Farmers Delivered to the Store

1. Assumed medium term copra price CIF is US$560/ton.

2. Costs CIF to FOB (averaged) for insurance and freight is US$100.

3. This gives an FOB price of US$460/ton.

4. The exchange rate used is WS$1.00 = US$0.45.

5. The FOB price is therefore WS$1022/ton.

6. The cost from FOB to Copra Board store are WS$130/ton for selling costs, transport, inspection fees, grading, fumigation and a shrinkage factor. This includes an export levy of $45 based on the above FOB price.

7. The at store price is therefore WS$892/ton, or 40 sene/lb for the financial analysis.

8. For the economic analysis the export levy is added back into the at store price. This is because the export levy is a transfer payment and not a resource cost to the nation.

The at-store price for the economic analysis is WS$937/ton, or 42 sene/lb.

Cocoa Product Prices

The World Bank Commodity Price Forecast in US dollars per kilogram are:

Year	1988	1989	1990	1995	2000
Real Price (1985 USc/kg)	114	89	73	72	108
Nominal Price	159	127	117	142	264

Relationship between Projected CIF Price and Prices to the Farmer delivered to the Store

1. Assumed medium term real CIF price is US$ 1400/ton
2. Costs from CIF to FOB for insurance and freight are US$ 400.
3. The FOB price is US$ 1000/ton
4. The exchange rate used is WS$ 1.00 = US$0.45.
5. Thus the FOB price is WS$ 2200
6. The costs from FOB to the Cocoa Board store total $ 800 covering selling costs, transport, inspection fees, grading, fumigation and a shrinkage factor. This also includes an export levy of 5% on the FOB value of $105.
7. Thus the financial price to the farmer delivered to the Cocoa Board store is $ 1400/ton or 62 sene/lb.
8. The economic price for cocoa bean delivered to the Cocoa Board store is $ 1505 or 67 sene/lb, obtained by adding back in the export levy.

Coffee Product Prices

The World Bank Commodity Price Forecast in US dollars per kilogram are:

Year	1988	1989	1990	1995	2000
Real Price (1985 USc/kg)	218	201	168	185	201
Nominal Price	303	287	267	364	492

The World Bank forecast is for Arabica coffee bean and there is a price discount of 70 percent for Robusta beans.

Relationship between Projected CIF Price and Price to the Farmer for Dried Cherry collected by the Processor

1. The assumed medium term real CIF price for Robusta coffee is US$ 2540/ton.

2. The costs from CIF to FOB for insurance and freight are US$400.

3. The FOB price is US$2140/ton.

4. The assumed exchange rate is WS$ 1.00 = US$ 0.45.

5. Thus the FOB price is WS$ 4755.

6. The costs for FOB to the farm gate for dried cherry collected by a private processor with bags provided is estimated at WS$1655 including transport, processing, grading, and insurance. An export levy has been allowed on the same basis as for coconut oil and cocoa at 5% of the FOB price, or $230.

7. Thus the price at the farm gate for the financial analysis is WS$3100/ton or $1.40/lb. For the economic analysis the export levy is added back in to give a price of WS$3330/ton or $1.48/lb.

Banana Prices

The price offered by New Zealand importers in March 1989 was FOB NZ$ 9.00 per 40lb carton. The June equivalent price may have been influenced by the rate of inflation in New Zealand and other market influences so that it is not possible to predict a price movement in any particular direction. With no more recent information available to Samoan exporters the March price is assumed to apply as at June 1989.

The equivalent Tala price based on the June exchange rate with the New Zealand dollar (WS$ 1.00 = NZ$ 0.77) is WS$ 11.70 per 40lb carton.

The costs from FOB to farm gate for packed cartons, covers transport, loading into containers, cool storage and wharfage and equals $1.40 per carton. This includes an export levy of 3% or 33 sene.

Thus farm gate prices are $10.30 per carton for the financial analysis and $10.63 for the economic analysis. The price used in the gross margin analysis also has the material cost of the carton deducted at $4.00, giving net farm gate prices of $6.30 and $6.63 per carton.

Alternative markets are local sales of green bananas for which the June 1989 price recorded by the Department of Statistics is 16 sene per lb. This price equivalent to $7.00 per bunch. The Apia Bottling Company's plant at Alafua had a June price of 45 sene per lb (net of stalk) for bananas processed into pulp.

Fruit Prices

The Food Processing Laboratory at Alafua, now a private company continues to be the main market for fruit products.

Their prices as at June 1989 were:

		WS$ per kg
i.	Passionfruit	0.48
ii.	Mango	0.35

Vegetable Prices

Local market prices reported by the Department of Statistics as at June 1989 were:

		WS$ per lb
i.	Cucumber	0.40
ii.	Tomato	1.46
iii.	Chinese Cabbage	0.80

The cucumber and chinese cabbage prices are assumed to represent an average price for projecting returns. However a price of $1.00 per lb was taken as an average price for projecting the value of tomato production.

Taro Prices

The Produce Marketing Division reported that an average annual price for taro exported to New Zealand as at June 1989, to be WS$26 per 70lb case. This is equivalent to a financial price of 35 sene per lb delivered to PMD and an economic price of 36 sene per lb.

Beef Prices

The price for beef carcass delivered to wholesalers in Apia is projected at $1.35 per lb as at June 1989.

Timber Prices

World Bank price projections for timber were not available. The price for sawn local timber was $466 per m^3 as at June 1989. Based on imported sawn timber for a range of grades Groome (1987) used $400 per m^3. From this Groome obtained a stumpage value net of logging and transport costs of \$35 per m^3. Armitage, Bartle and Reti (1984), used a price differential based on Auckland wholesale prices of 1:2 for utility timber (*Eucalyptus deglupta*) and hardwoods (Mahogany). For June 1989 financial prices therefore, stumpage values of \$30 per m^3 for *E. deglupta* and \$60 per mm^3 for Mahogany. Economic stumpage values are increased by 50 percent as a reflection of the resource scarcity for timber in Western Samoa.

A8.1.3 Costs Used in the Gross Margin Analysis

The Agricultural Store Corporation (ASC) provided costs for standard input items used in the enterprises. Sale price for a number of items is subsidised by Government. The ASC provided the subsidised (sale) price and the economic (full) price at the point of retail for use in the economic analyses. The data is summarised in Table A8.3.

Table A8.3 *Agricultural store prices*

Group	Item	Quantity	Item Price		Unit Price	
			Sale Price	Full Price	Sale Price	Full Price
Fertilizer	NPK 12.5.20	50 kg	11.00	59.00	0.10	0.54
	Ammonium sulphate		50 kg		52.00	0.47
	Potass. chloride	50 kg		62.00		0.56
	Vegetable Mix	50 kg		62.00		0.56
	NPK 20.10.10	50 kg		34.37		0.31
Herbicides	Roundup	5 Litre	151.00	300.00	30.00	60.00
	Gramoxone	5 Litre	52.00	72.00	10.40	14.40
Pesticides	Calixin	5 Litre	136.80	239.60	27.36	47.92
	Punch	250 mls	35.00	62.00	140.00	248.00
	Mistoil	206 lit	307.50	560.00	1.50	2.73
	Actellic	25 kg		264.00		4.80
	Vydate	4.5 lit	112.50	162.00	25.00	36.00
	Ambush	1 Litre		31.00		31.00
	Benlate	1 kg		96.40		96.40
	Orthene	75 gm		9.00		0.12
Equipment	DrainSpade			45.50		
	TubSpade			32.00		
	Fork			39.00		
	BKnife			10.00		
	Rake			22.50		
	Crowbar			40.00		
	CocoaKnife			13.00		
	Misblower			1456.00		
	Knapsack			200.00		
	S/MothInjector			93.00		
	Wheelbarrow			180.00		

A8.1.4. Gross Margin results for Crops and Forestry Enterprises

The analysis of crop and forestry enterprises based on the physical and price assumptions given was undertaken using MULBUD.

The programme output provides tables showing input and output assumptions in physical and financial terms. The results are presented under two sections. Sensitivity Analysis and Summary Results. The Sensitivity Analysis includes:

(a) sum of net present values (SNPV) for four specified interest or discount rates,

(b) the internal rate of return,

(c) the SNPVs at a 10 percent discount rate for a range of increases and decreases in assumed material costs and gross revenues.

The range in gross revenue, from plus 20 percent to minus 20 percent allows the impact of land capability to be assessed.

The Summary Results table presents data for each year of the analysis. It is particularly useful in the financial analysis, indicating to farmers and advisors the period in years and the quantity of negative cash flow which would need to be paid for by savings or borrowing. The net revenue per day gives a return to labour which farmers can relate to their daily wage.

The MULBUD outputs show the following for each enterprise:

(a) economic labour requirements
(b) economic material requirements
(c) economic additional inputs
(d) economic output
(e) economic sensitivity analysis
(f) financial summary results

The intercropping enterprises were also developed using MULBUD. The intercropping analysis allows for shorter term crops to be interplanted with a longer term base enterprise. Assumptions on the use of land area and light can be tested and planting intensity assumptions adjusted. Interplanting changes the joint weeding, fertiliser and pest control requirements and interactions can be specified. The total labour requirements are checked against the family labour constraints.

The intercropping options tested were

(a) Hybrid coconut with Amelonado cocoa from year 17.

The low economic return for *Amelonado cocoa* adds very little to the return of hybrid coconut in the intercropping enterprise compared with the monocrop result.

(b) Local tall coconut with taro at establishment and low input coffee

from year 4.

The addition of a high return cash crop at establishment followed by the coffee intercrop which is also capable of a high return, takes local tall coconuts from a modest return when monocropped, to exceed the highest single enterprise returns, except for the agroforestry enterprise.

A8.2. GROSS MARGIN ANALYSIS OF CATTLE PRODUCTION

Beef cattle production is evaluated as a land use option. The "plantation case" is cattle breeding based a 30 cow and one bull herd suited to larger production areas. Recommended inputs are assumed. The smallholder option is cattle fattening based on purchasing 8 weaner steers each year.

Both options can utilize areas under coconuts, while some cattle breeding production uses existing open grassland areas. The case of clearing land for cattle breeding is also examined.

A8.2.1 Outline of Assumptions and Analysis

Cattle Breeding

(a) Capital Inputs (Unit Costs)

i. Fencing: inputs based on the FAO Manual "Cattle Production in Western Samoa", 1988.

ii. Water supply: inputs based on proposals to provide catchment and storage for Togitogiga.

iii. Stockyards: based on the Department of Agriculture Information booklet 'Fausiaina o se Sitokia (50 Povi)' 1982.

iv. Stock purchases is based on WSTEC and the DAFF sources.

v. Land Development: assumes light brush control of suitable areas under coconuts or on areas of open grassland. Land clearing and pasture establishment costs are presented for the case of developing forest areas for cattle production.The economic and environmental aspects of this latter case are noted.

(b) Stock Production Assumptions

Deriving a balanced herd number based on purchasing 30 heifers, follows the method shown in the FAO Cattle Production Manual, 1988. Stock units for the balanced herd are also based on this Manual. Timing of the herd development is presented.

(c) Stocking Rate and Project Capital Costs

The land capability assessment is a significant factor in determining stocking rate. Therefore economic results are calculated for land capability levels, "good land capability" and land with limitations, such as thin soils, or soils with moisture deficits of more than 30 days.

The other major variation in stocking rate is between open grassland and areas under coconuts. These options are presented.

Project capital costs are developed for the different stocking rate cases and for the alternative land development cases.

(d) Operational Costs

These include the costs for maintenance of fencing, the stockyard and water supply, at 1 percent of capital cost, and the costs for stock needs. Fertiliser is not expected to be used even for this "plantation case". The labour input for stockwork and maintenance is expected to be provided by family labour. A requirement of 50 days per annum is used. A replacement bull is purchased every 2 years.

(e) Revenue

The price per kg of dressed carcass paid by retailers in Apia, less an average estimate of transport costs to Apia, is used to value output. Weight, numbers and age at slaughter are given.

(f) Cash Flows

Costs and revenues are projected over time for the five cases illustrating land capability and land development differences. Results are presented for net present value at 10% and for the Internal Rate of Return (IRR). From this, per acre results are provided for comparison with crop and forestry gross margins.

Cattle Fattening

(a) Capital Inputs (Unit Costs)

i. Fencing: as for cattle breeding.

ii. Water supply: with and without water supply cases are presented. The provision of water is based on a simple dam and pipe to a central trough arrangement.

iii. Stockyard: a small yard, forcing pen, loading ramp and race using bush materials is used.

iv. Stock: as for cattle breeding.

v. Land development: only the light brush-control case is considered.

(b) Stock Production Assumptions

Growth rates with and without water uses information obtained in trial work at Vailele (Reynolds, 1975). Stock units are noted based on the purchase of 8 weaner steers each year and rearing for two years before selling.

(c) Stocking Rate and Project Capital Costs

Only the case of using land under coconuts is examined as this is the main option open to small farmers. Both good and limited land capability units are used and appropriate stocking rates are used for each case. Capital estimates are developed for the stocking rate variations.

(d) Operational Costs

Maintenance of fencing and the water supply is provided for at 1.5 percent of capital cost. No fertiliser or stock requirements are assumed. family labour is provided at an input of 12 days per year (equivalent to 2 hrs per week).

(e) Revenue: as for cattle breeding.

(f) Cash Flows: as for cattle breeding.

A8.2.2. Details of the Assumptions for the Analysis

Cattle Breeding

(a) Capital Inputs (Unit Costs)

See Table A8.4.

(b) Stock Production Assumptions

Losses:	breeders	3%
	dry stock	1%
Calving:	assessed at weaning	70%
Replacements:	of breeders per year	20%
	of bull	every 2 years
First calving:		at 2.5+ years
Sale Stock:		at 2.5-3 years,
Cow : Bull Ratio:		30 cows/bull

i. *Herd Structure*

Cows 30 — Losses (3%) 1

Calves to Weaning 70%

Bull Calves 10 — Heifer Calves 10

Losses Weaner to Yearling 3%

0 — 1

Yrlg Steers 10 — Yrlg Heifers 9 — Replacement to Breeding Herd

Losses Yrlg to 2 Year 1%

1 — 0

2 Yr Steers 9 — 2 Yr Heifers 9

2 Yr Heifers 6

Sale Stock

2 Yr Steers 9 — 2 Yr Heifers 3

Cull Bull 0.5 — Cull Cows 5

ii. *Stock Units*

Type of Stock	No	Units	Total
Breeding Cows	30	1.0	30
Calves to Weaning	20	0.2	4
Yrlg Heif/Steers	19	0.6	11.4
2 Yr Heif/Steers	18	0.8	14.4
Breeding Bull	1	1.2	1.2
Total	88		61

(c) Stocking Rate and Project Capital Costs

i. *Stocking Rates*

Cases		*Acre/SU*
1.	Under coconut, good land capability	2
2.	Under coconut, land with limitations	3
3.	Open grassland, good land capability	1.5
4.	Open grassland, land with limitation	2
5.	Developed from forest, good land	3*

*but increasing to 1.5 acre/SU by year 10.

ii. *Project Capital Costs*

See Table A8.5.

(d) Operational Costs

Labour: 50 days per year for maintenance and stock work

Stock Needs: $300 per year for stock needs such as drench, salt, and tags/brands

Materials: 1% of fence, water and stockyard capital cost

(e) Stock Revenue

Steers and cull bull at 440 lb carcass weight

Cull heifers and cows at 400 lb carcass weight

Price per lb Carcass Weight: $1.30 (net of $0.05/lb transport)

Cattle Fattening

(a) Capital Inputs (Unit Costs)

See Table A8.4.

(b) Stock Production Assumptions

Losses: 1 over the two year fattening period

Purchase: 8-month old weaners assumed to be around 240 lbs liveweight, at a cost of $150.

Weight Gains: without water: liveweight gain of 180 lbs per year

with water: liveweight gain of 280 lbs per year

(c) Stocking Rate and Project Capital Costs

i. *Stocking Rate:*	*Acre/SU*
Under coconuts, good land capability	2
Under coconuts, land with limitations	3

ii. *Project Development Costs*

See Table A8.6.

(d) Operational Costs

Labour: 12 days per year for maintenance and stock work

Materials: 1.5% of fence, water and stockyard capital cost

(e) Revenue

31 to 32 mth steers:

without water: carcass weight of 340 lbs

with water: carcass weight of 400 lbs

Price per lb Carcass Weight: $1.30 (net of $0.05/lb transport)

A8.2.3 Results of the Analysis

The results of the cash flow analyses are shown in Tables A8.8 to A8.16 and summarised in Table A8.17.

Cattle breeding enterprises meet a 10 percent rate of return criteria on land of good capability and also on existing open grassland requiring limited clearing. Land with limitations such as periods of moisture deficit reducing pasture production, and also under coconuts, requires a significantly greater area to be fenced and watered, and gives a rate of return in the order of 8.5 percent. However the added benefits to coconut production from a well managed cattle operation under coconuts would clearly ensure that such a project meet a 10 percent rate of return.

Cattle production based on the development of uncleared bush areas is economically marginal giving only a 4 percent rate of return. Because it involves extensive clearing of forest areas it can also have important environmental impacts reducing the level of water flow out of catchment areas during the dry season and allowing increased flood flows during the wet season.

Cattle fattening by farmers with smaller areas of land under coconuts provides good rates of return (from 16 to 24 percent) even where there are some limitations to land capability for cattle production. However even for these cases 20 to 30 acres has been put forward as a minimum viable unit. Provision of water adds significantly to the rates of return achieved (an extra 5 percent or an additional $4000 to the net present value of the project.

For both cattle breeding and fattening net revenue per labour day is high (from $120 to $200 per day), while return per acre is low (a NPV at 10 percent of -$132 to $360 per acre) in comparison with cropping options.

Table A8.4 *Cattle : capital inputs (unit costs)*

Component	Item	Amount	Total Cost WS$	Unit	Cost/Unit WS$
Water Supply					
	Catchment & Reservoir	25x30m 20000gal	20000	gal	1.00
	Trough	100 gal			140.00
	Pipe	20mm x 50m	113	metre	2.26
		25mm x 50m	143	metre	2.86
	Intake		250		
Fencing	Per Mile				
	Str Posts	5	85		17.00
	Posts	352	1405		4.00
	Barb Wire	28	2380	coil	85.00
	Staples	168	202	lb	1.20
	Labour	25	250	days	10.00
	Total/mile		4322		
	Total/km		2687		
Stock	W. Heifers				150.00
	W. Steers				160.00
	Yrlg Bull				250.00
Stockyard	breeding		2220		
	fattening		600		

Table A8.5 *Cattle breeding: project development costs*

	Case 1	Case 2	Case 3	Case 4	Case 5
Acre/SU	2	3	1.5	2	3-1.5
Area (acres)	120	180	90	120	180
Capital Item					
Fencing					
Amount (km)	7.7	9.35	6.66	7.7	9.35
$ (2687/km)	20690	25123	17895	20690	25123
Water Supply					
Reservoir/Catchment					
Amt. (6000gal)					
$ ($1/gal)	6000	6000	6000	6000	6000
Pipe (20mm)					
Amt. (metre)	697	854	605	697	854
$ ($2.26/m)	1575	1930	1367	1575	1930
Troughs (100gal)					
Amount	3	4	2	3	4
$ ($140/troug	420	560	280	420	560
Sub Total	7995	8490	7647	7995	8490
Stockyard	2220	2220	2220	2220	2220
Stock					
Amt (30Heifers)					
$ ($150each)	4500	4500	4500	4500	4500
Amt (1Bull)					
$ ($250each)	250	250	250	250	250
Land Development					
Days/Acre	2	2	3	3	15
Amt (days)	240	360	270	360	2700
$ ($10/day)	2400	3600	2700	3600	27000
Total Capital	**38055**	**44183**	**35213**	**39255**	**67583**

Table A8.6 *Cattle fattening: project development costs*

	Case 1	Case 2
Acre/SU	2	3
Area (acres)	20	30
Capital Item		
Fencing		
Amount (km)	1.14	1.4
$ (2687/km)	3063	3762
Water Supply		
Intake		
$	250	250
Pipe (20mm)		
Amt. (metre)	280	350
$ ($2.26/m)	633	791
Troughs (100gal)		
Amount	1	1
$ ($140/trough)	140	140
Sub Total	1023	1181
Stockyard	500	500
Stock		
Amt (8 Steers)		
$ ($150each)	1200	1200
Land Development		
Days/Acre	2	2
Amt (days)	40	60
Total Capital	**5786**	**6643**

Table A8.7 *Timing of stock activities and capital inputs*

Project Year	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year
Stock Activities (shows age of stk)						
Cattle Breeding						
Purchase heifers	6 mths					
Purchase bull		18 mth				
Mating		21-24 mth				
Calving			30-33 mth			
Sale Stock						30 mth
Stock Units	11	15	35	47	61	61
Cattle Fattening						
Purchase Steers	7-8 mth	7-8 mth	7-8 mth	...		
Sale of Steers			31-32mth	31-32mth	31-32mth	...
Stock Units	4.8	10.4	10.4	10.4	10.4	...
Capital Inputs (% by Year) Cattle Breeding						
Fencing	50		50			
Water		100				
Stockyard		100				
Land Developmt	50		50			
Cattle Fattening						
Fencing	100					
Water		100				
Stockyard		100				
Land Developmt	100					

Table A8.8 *Cattle breeding cash flow. Case 1: Under coconuts, good land capability*

Year	COSTS Capital Fencing	Water	Stkyard	Land Dev	Stock	Operational Material	Stock	Labour (days)	Total	REVENUE	Net Revenue	Net Rev per Day	Cum Cap F+W+S
0	10345			1200	4500				16045		-16045		10345
1		7995	2220		250		300	50	10765		-10765	-215	20560
2	10345			1200		103	300	50	11948		-11948	-239	30905
3						206	550	50	756	572	-184	-4	30905
4						309	300	50	609		-609	-12	30905
5						309	550	50	859	572	-287	-6	30905
6						309	300	50	609	9308	8699	174	30905
7						309	550	50	859	9880	9021	180	30905
8						309	300	50	609	9308	8699	174	30905
9						309	550	50	859	9880	9021	180	30905
10						309	300	50	609	9308	8699	174	30905
11						309	550	50	859	9880	9021	180	30905
12						309	300	50	609	9308	8699	174	30905
13						309	550	50	859	9880	9021	180	30905
14						309	300	50	609	9308	8699	174	30905
15						309	550	50	859	25780	24921	498	30905
									NPV @ 10%		1038		
									IRR %		10.4		

Table A8.9 *Cattle breeding cash flow. Case 2: Under Coconuts, Land with Limitations*

Year	COSTS Capital Fencing	Water	Stkyard	Land Dev	Stock	Operational Material	Stock	Labour (days)	Total	REVENUE	Net Revenue	Net Rev per Day	Cum Cap F+W+S
0	12562			1800	4500				18862		-18862		12562
1		8490	2220		250		300	50	11260		-11260	-225	23272
2	12562			1800		126	300	50	14788		-14788	-296	35834
3						233	550	50	783	572	-211	-4	35834
4						358	300	50	658		-658	-13	35834
5						358	550	50	908	572	-336	-7	35834
6						358	300	50	658	9308	8650	173	35834
7						358	550	50	908	9880	8972	179	35834
8						358	300	50	658	9308	8650	173	35834
9						358	550	50	908	9880	8972	179	35834
10						358	300	50	658	9308	8650	173	35834
11						358	550	50	908	9880	8972	179	35834
12						358	300	50	658	9308	8650	173	35834
13						358	550	50	908	9880	8972	179	35834
14						358	300	50	658	9308	8650	173	35834
15						358	550	50	908	25780	24872	497	35834
									NPV @ 10%		-4313		
									IRR %		8.6		

Table A8.10 *Cattle breeding cash flow. Case 3: Open grassland, good land capability*

Year	COSTS Capital Fencing	Water	Stkyard	Land Dev	Stock	Operational Material	Stock	Labour (days)	Total	REVENUE	Net Revenue	Net Rev per Day	Cum Cap F+W+S
0	8948			1350	4500				14798		-14798		8948
1		7647	2220		250		300	50	10417		-10417	-208	18815
2	8948			1350		89	300	50	10687		-10687	-214	27763
3						188	550	50	738	572	-166	-3	27763
4						278	300	50	578		-578	-12	27763
5						278	550	50	828	572	-256	-5	27763
6						278	300	50	578	9308	8730	175	27763
7						278	550	50	828	9880	9052	181	27763
8						278	300	50	578	9308	8730	175	27763
9						278	550	50	828	9880	9052	181	27763
10						278	300	50	578	9308	8730	175	27763
11						278	550	50	828	9880	9052	181	27763
12						278	300	50	578	9308	8730	175	27763
13						278	550	50	828	9880	9052	181	27763
14						278	300	50	578	9308	8730	175	27763
15						278	550	50	828	25780	24952	499	27763
									NPV @ 10%		3565		
									IRR %		11.3		

Table A8.11 *Cattle breeding cash flow. Case 4: Open grassland, land with limitations*

Year	COSTS Capital Fencing	Water	Stkyard	Land Dev	Stock	Operational Material	Operational Stock	Labour (days)	Total	REVENUE	Net Revenue	Net Rev per Day	Cum Cap F+W+S
0	10345			1800	4500				16645		-16645		10345
1		7995	2220		250		300	50	10765		-10765	-215	20560
2	10345			1800		103	300	50	12548		-12548	-251	30905
3						206	550	50	756	572	-184	-4	30905
4						309	300	50	609		-609	-12	30905
5						309	550	50	859	572	-287	-6	30905
6						309	300	50	609	9308	8699	174	30905
7						309	550	50	859	9880	9021	180	30905
8						309	300	50	609	9308	8699	174	30905
9						309	550	50	859	9880	9021	180	30905
10						309	300	50	609	9308	8699	174	30905
11						309	550	50	859	9880	9021	180	30905
12						309	300	50	609	9308	8699	174	30905
13						309	550	50	859	9880	9021	180	30905
14						309	300	50	609	9308	8699	174	30905
15						309	550	50	859	5780	24921	498	30905

NPV @ 10% 42

IRR % 10.0

Table A8.12 *Cattle breeding cash flow. Case 5: Land developed from forest*

Year	COSTS Capital Fencing	Water	Stkyard	Land Dev	Stock	Operational Material	Stock	Labour (days)	Total	REVENUE	Net Revenue	Net Rev per Day	Cum Cap F+W+S
0	12562			13500	4500				30562		-30562		12562
1		8490	2220		250		300	50	11260		-11260	-225	23272
2	12562			13500		126	300	50	26488		-26488	-530	35834
3						233	550	50	783	572	-211	-4	35834
4						358	300	50	658		-658	-13	35834
5						358	550	50	908	572	-336	-7	35834
6						358	300	50	658	9308	8650	173	35834
7						358	550	50	908	9880	8972	179	35834
8						358	300	50	658	9308	8650	173	35834
9						358	550	50	908	9880	8972	179	35834
10						358	300	50	658	9308	8650	173	35834
11						358	550	50	908	9880	8972	179	35834
12						358	300	50	658	9308	8650	173	35834
13						358	550	50	908	9880	8972	179	35834
14						358	300	50	658	9308	8650	173	35834
15						358	550	50	908	25780	24872	497	35834
									NPV @ 10%		-23739		
									IRR %		4.1		

Table A8.13 *Cattle fattening cash flow. Case 1: Under coconuts, good land capability, with water*

Year	COSTS Capital Fencing	Water	Stkyard	Land Dev	Stock	Operational Material	Stock	Labour (days)	Total	REVENUE	Net Revenue	Total Labour (Days)	Net Rev per Day	Cum Cap F+W+S
0	3063			40					3063		-3063	40	-77	3063
1		1023	500		1200		0	12	2723		-2723	12	-227	4586
2					1200	46	0	12	1246		-1246	12	-104	4586
3					1200	69	0	12	1269	3640	2371	12	198	4586
4					1200	69	0	12	1269	3640	2371	12	198	4586
5					1200	69	0	12	1269	3640	2371	12	198	4586
6					1200	69	0	12	1269	3640	2371	12	198	4586
7					1200	69	0	12	1269	3640	2371	12	198	4586
8					1200	69	0	12	1269	3640	2371	12	198	4586
9					1200	69	0	12	1269	3640	2371	12	198	4586
10					1200	69	0	12	1269	3640	2371	12	198	4586
11					1200	69	0	12	1269	3640	2371	12	198	4586
12					1200	69	0	12	1269	3640	2371	12	198	4586
13					1200	69	0	12	1269	3640	2371	12	198	4586
14						69	0	12	69	3640	3571	12	298	4586
15						69	0	12	69	3640	3571	12	298	4586
										NPV @ 10%		7232		
										IRR %		24.2		

Table A8.14 *Cattle fattening cash flow. Case 2: Under coconuts, good land capability, without water*

Year	COSTS Capital Fencing	Water	Stkyard	Land Dev	Stock	Operational Material	Stock	Labour (days)	Total	REVENUE	Net Revenue	Total Labour (Days)	Net Rev per Day	Cum Cap F+W+S
0	3063			40					3063		-3063	40	-77	3063
1		0	500		1200		0	12	1700		-1700	12	-142	3563
2					1200	46	0	12	1246		-1246	12	-104	3563
3					1200	53	0	12	1253	2730	1477	12	123	3563
4					1200	53	0	12	1253	2730	1477	12	123	3563
5					1200	53	0	12	1253	2730	1477	12	123	3563
6					1200	53	0	12	1253	2730	1477	12	123	3563
7					1200	53	0	12	1253	2730	1477	12	123	3563
8					1200	53	0	12	1253	2730	1477	12	123	3563
9					1200	53	0	12	1253	2730	1477	12	123	3563
10					1200	53	0	12	1253	2730	1477	12	123	3563
11					1200	53	0	12	1253	2730	1477	12	123	3563
12					1200	53	0	12	1253	2730	1477	12	123	3563
13					1200	53	0	12	1253	2730	1477	12	123	3563
14						53	0	12	53	2730	2677	12	223	3563
15						53	0	12	53	2730	2677	12	223	3563
										NPV @ 10%			3303	
										IRR %			18.1	

Table A8.15 *Cattle fattening cash flow. Case 3: Under coconuts, land with limitations, with water*

Year	COSTS Capital Fencing	Water	Stkyard	Land Dev (Days)	Stock	Operational Material	Stock	Labour (days)	Total	REVENUE	Net Revenue	Total Labour (Days)	NET REV per Day
0	3762			60					3762		-3762	60	-63
1		1181	500		1200		0	12	2881		-2881	12	-240
2					1200	56	0	12	1256		-1256	12	-105
3					1200	82	0	12	1282	3640	2358	12	197
4					1200	82	0	12	1282	3640	2358	12	197
5					1200	82	0	12	1282	3640	2358	12	197
6					1200	82	0	12	1282	3640	2358	12	197
7					1200	82	0	12	1282	3640	2358	12	197
8					1200	82	0	12	1282	3640	2358	12	197
9					1200	82	0	12	1282	3640	2358	12	197
10					1200	82	0	12	1282	3640	2358	12	197
11					1200	82	0	12	1282	3640	2358	12	197
12					1200	82	0	12	1282	3640	2358	12	197
13					1200	82	0	12	1282	3640	2358	12	197
14						82	0	12	82	3640	3558	12	297
15						82	0	12	82	3640	3558	12	297
									NPV @ 10%		6390		
									IRR %		21.5		

Table A8.16 *Cattle fattening cash. Case 4: Under coconuts, land with limitations, without water*

Year	COSTS Capital Fencing	Water	Stkyard	Land Dev (Days)	Stock	Operational Material	Stock	Labour (days)	Total	REVENUE	Net Revenue	Total Labour (Days)	Net Rev per Day	Cum Cap F+W+S
0	3762			60					3762		-3762	60	-63	3762
1		0	500		1200		0	12	1700		-1700	12	-142	4262
2					1200	56	0	^R	1256		-1256	12	-105	4262
3					1200	64	0	12	1264	2730	1466	12	122	4262
4					1200	64	0	12	1264	2730	1466	12	122	4262
5					1200	64	0	12	1264	2730	1466	12	122	4262
6					1200	64	0	12	1264	2730	1466	12	122	4262
7					1200	64	0	12	1264	2730	1466	12	122	4262
8					1200	64	0	12	1264	2730	1466	12	122	4262
9					1200	64	0	12	1264	2730	1466	12	122	4262
10					1200	64	0	12	1264	2730	1466	12	122	4262
11					1200	64	0	12	1264	2730	1466	12	122	4262
12					1200	64	0	12	1264	2730	1466	12	122	4262
13					1200	64	0	12	1264	2730	1466	12	122	4262
14						64	0	12	64	2730	2666	12	222	4262
15						64	0	12	64	2730	2666	12	222	4262

NPV @ 10% 2604

IRR % 15.8

Table A8.17 *Summary of results*

	Case Description	PROJECT NPV @10%	IRR	Net Rev Per Day	Area (acre)	PER ACRE NPV 10%
Breeding	1 Under Cnut,Good Land	1038	10.6	174	120	8.65
	2 Under Cnut,Limited Land	-4313	8.6	173	180	-23.96
	3 Open Past,Good Land	3565	11.3	175	90	39.61
	4 Open Past,Limited Land	42	10.0	174	120	0.35
	5 Dev from Forest	-23739	4.1	173	180	-131.88
Fattening	1 Good Land w Water	7232	24.2	198	20	361.60
	2 Good Land w/out Water	3303	18.1	123	20	165.15
	3 Limited Land w Water	6390	21.5	197	30	213.00
	4 Limitd Land w/out Water	2604	15.8	122	30	86.80

A8.3. COST BENEFIT ANALYSIS OF WATERSHED PROTECTION: AN EXAMPLE INVOLVING UNPRICED VALUES

The details of the programme proposed for implementation in the Vaisigano Pilot Watershed Management Project are currently under development based on an updated survey in early 1989. The survey considered land use, topography and soil to arrive at recommended management. In a similar exercise in 1983 Nelson D. classified the Vaisigano catchment as follows:

i Lowland plain and bottoms: 52 ha, flood prone, needs bank protection;

ii Valley Slopes and foothills: 630 ha, low natural fertility, has long natural landslides, some erosion to catchment, needs protection forest.

iii Valley side slopes (lower elevation): 60 ha, low-mod fertility, intensive cultivation, needs agroforestry;

iv Upland and highland ridges: 657 ha, very low fertility, high runoff areas, needs to be kept in protection forest;

v Bottomlands: 236 ha, includes fertile soils, intensive use in parts, needs buffer strip between plantings and stream (5m). In upper section acts as buffer between side slopes and stream.

vi Uplands: soils of low to very low natural fertility. 227 ha identified for protection forest plus forest buffer around upland plateau areas of 1340 ha.

The extent to which the catchment condition has changed between the two surveys is not known. The costs of implementing a watershed protection project along the lines of that proposed for the Vaisigano Pilot Watershed Management Project were discussed with the Officer in charge of the Community Forestry programme, Tuli Taogaga. The programme includes soil conservation works in some sensitive areas to prevent debris from roads and drains flowing into the catchment. Alternative land use (agroforestry) is to be promoted for sensitive valley side slopes and in important buffer areas. Land use controls will be used to enforce buffer areas and areas needing protection forests.

Records were available for initial soil conservation works undertaken in the catchment.

A8.3.1 Costs

Soil Conservation Works

The costs for gully control covered construction of a three layer gabion wall and two plank and pole check dams. Costs were:

	$
materials (wire, stone, timber, seedlings)	695
labour (41 days @ $10/day)	410
total	**1105**

The costs of slope stabilization included a further gabion wall together with 63 metres of wattling and brushwood check dams arranged in 8 rows across the slope.

Costs were:	$
materials (similar to the above)	1350
labour (80 days @ $10/day)	800
total	**2150**

Maintenance of these works is provided for at 5 percent of the capital cost ($3255), or $163 per year.

No assessment has been made at this stage of the need for further works of this nature, which were proposed to deal with problems created by hydro project roads put into the catchment in the early 1980's.

For the purposes of this exercise two further expenditures of identical size are projected for the next two project years.

Promotion of Alternative Land Use

The FAO programme has provided communication equipment to aid the extension programme. This cost WS$3700 plus WS $22400 for a vehicle. The Community Forestry programme has an operating budget of $36000, of which $2250 would support the extension programme, plus $4000 for the operation of the vehicle. It is assumed that 20 percent of the Community Forester's time and 30 percent of the capital and operational budget could be realistically attributed to the Vaisigano Project.

Therefore costs are:	$
Capital items (vehicle, equipment)	8500
Operating (extension materials, etc)	1875
Staff time	1600

Controls on Land Use

The Water Section of the Public Works Department advised that a person had been appointed with agreement of the village authorities, to police the legislation (Water Act, 1965) that prohibits cultivation within 66 yards of the river bank. The village had agreed that farmers understood the law and the need for it, but felt that enforcement of penalties was necessary to make it effective. Enforcement costs are based on the surveillance of the appointed person and the prosecution by Police.

Therefore costs are:	$
Surveillance (wages cost, transport)	2500
Prosecution (5 cases, net costs)	2500

The above programme is undertaken over a period of three years though some ongoing administration of controls is projected.

A8.3.2 Benefits

From discussion with relevant Departments and within the Economic

Analysis and Planning Unit (EAPU) of DAFF, benefits were investigated from the expected impacts of the programme on:

1. the outputs of alternative land use;
2. improved water quality;
3. increased dry season flows;
4. reduced soil erosion;
5. reduced wet season flood flows.

Benefits from Alternative Land Use

The net production benefit was investigated for the adoption of agroforestry as an alternative land use to taro production. The agroforestry system is based on continuing production of a plot of land with taro interplanted with a leguminous tree such as Gliricidia or Calliandra. Data from trial plots of agroforestry have demonstrated sustained production over 5 years with some increase in corm size of the taro. Taro production is based on gross margins developed in the EAPU of DAFF. It assumes that 1 acre is cleared and planted each year on a six year rotation. Other differences between the two are:

i. agroforestry requires extra labour for clearing and planting in the first year to establish the legume. An allowance is also made for pruning the legume. However the repeated clearing of new land for planting is avoided.

ii. a yield benefit is allowed after 3 years of mulching with legume cuttings, with an extra 0.3 lb per corm in the 4th and 5th year, and an extra 0.5 lb from the 6th year.

Details are given in the MULBUD tables for taro and agroforestry. Using the net revenue data for taro and projecting it over a six year planting cycle the total net revenue and the sum of net present value for taro is produced in the table below to compare with the sum of net present value for agroforestry.

Note that the taro production occurs on 6 acres while agroforestry requires 1 acre. Thus the adoption by farmers of agroforestry involves a benefit of $1729 per acre substituted in net present value terms, plus the release of 5 acres for alternative uses or protection plantings.

Table A8.18. *Taro and Agroforestry Net Present Values*

Year	Taro Net Rev	Agroforestry Net Rev	Difference Net Rev
1	-947	-1132	-185
2	2741	3566	825
3	3380	3566	186
4	3380	3566	186
5	3380	4012	632
6	3380	4012	632
7	4327	4412	85
SNPV	**13705**	**15434**	**1729**

The above projection is for one planting rotation for taro. Over a further period agroforestry is assumed to sustain a net revenue of $4012, while the taro production cycle would continue to produce a net revenue of $3380 from year 7 through to the end of the 20 years used to evaluate the project.

From the project activities for encouraging agroforestry it is assumed that 50 percent of the 150 acres recommended for agroforestry is taken out of straight taro production and put into agroforestry. That is, 75 acres currently sustaining 12.5 acres of taro on a six year rotation, is replaced by 12.5 acres of agroforestry. The rate of development is shown below:

Year	2	3	4	5
Area into Agroforestry				
New acres	1	2	4	5.5
Total acres	1	3	7	12.5

To develop the project benefit it is necessary to use the difference in net revenue flows for agroforestry and taro and to multiply up that net revenue difference by the number of acres substituted in each year. This is shown in Table A8.20.

Benefits from Improved Water Quality

Data was obtained from the Health Planning Unit of the Health Department on the relationship between water quality and the incidence of water borne disease. Gastroenteritis and diarrhoea were recorded for 1986 as the second highest cause of morbidity with 1356 cases. Not all could be attributed to water quality but coliform levels in drinking water suggest that 80 percent of cases could be from that source.

Contamination of the water supply, however, is not a consequence of land use itself but of human and animal activity in areas adjacent to water sources. The catchment plan has these areas zoned for retaining in protection forest, but the pilot project activities are more concerned with land use resulting in soil erosion and poor hydraulic condition of the catchment. The two requirements are closely related and implementation of controls could be undertaken to meet both needs.

Water treatment proposals of the new Apia Water Supply Project overcome this problem to a significant degree. Thus benefits to the pilot project from improved health are not expected. Should a health benefit need to be valued, approaches might include; fewer days off work due to sickness valued at the average daily wage; or reduced costs of medication and treatment where hospitalization was involved.

Benefits from Increased Dry Season Flows

Data on river flows in the East branch of the Vaisigano have been recorded since 1974 and have been the basis for developing hydro power generation and for projecting supplies for water consumption. The records were briefly examined to see if there was an indication of a trend to lower dry season flows and larger peak wet season flood flows which might suggest a poorer hydraulic condition in the catchment. Only monthly average flows were examined and there was not the opportunity to have statistical analyses done on the data. Graphing monthly average flows for the months of June, July and August was done to observe any obvious trends. Visual inspection of the June and July flows suggests a decline of 0.165 m^3/sec or 14256 m^3/day. This decline is based on an average flow of 0.571 m^3/sec and 49334 m^3/day.

(a) Water Supply Uses

The Apia water supply is currently being upgraded based on water from the Fuluasou and Vaisigano catchments. Sources from the Vaisigano include Alaoa springs, Alaoa tailrace and East Vaisigano which are expected to serve 54 percent of the population in the scheme area. The scheme will provide filtered and treated water based on sedimentation, slow sand filtration and post chlorination. Based on investment costs and operation costs discounted at 5%, and the projected quantity of water delivered, the marginal cost of water was assessed as $0.31 per cubic metre in 1984 tala.

Total population served by the Apia water supply was 40000 in 1984. Usage estimates made for the Phase 1 Review and Upgrading Feasibility Study were:

Consumption/person/day	(litres)
current use	270-400
losses	300-400
total	**685**

The total water input was on average 28000 m^3 per day. The new scheme is based on a smaller total input of around 17000 to 23500 depending on population projections and a per person consumption of either 240 or 200 litres/day. The reduced consumption estimate comes from the saving of the high level of losses in the old water supply and from the proposal the meter water use and apply the marginal cost tariff.

Because water supply use is expected to decline with the implementation of the new water supply scheme, a benefit for water supply use from increased dry season flow may not be significant. The Vaisigano east source for the scheme is expected to provide 0.15 m^3/sec. This appears to be well within the capacity of low flows measured during the 1982 to 1984 period. However the recording for July 1988 was 0.08 m^3/sec. Although the new water supply does not depend on the Vaisigano east source, the decline in this area could be expected in the other sources in the catchment.

A reduction of 1000 m^3/day each year for the past 14 years for June and July from the Vaisigano east source, if continued for a further 15 years, would result in restrictions in the dry season supply. Costs of restrictions can be observed with the present system, where industry loses production from lack of water or households are faced with additional costs associated with travelling to obtain essential supplies. A long term benefit from saving these costs could be projected.

(b) Hydro Electricity Uses

Data was obtained from the Electric Power Corporation on the difference in the costs of generating electricity from the alternative hydro and diesel sources. The costs for 1988 generation were as follows:

Costs in WS$ 000's (1988)

	Upolu		Savaii
Item	**Hydro**	**Diesel**	**Diesel**
Fuel oil		2288	385.6
Lub. oil		129.3	41.7
Insurance	118.4	34.8	6.1
Op exes	54.3	159.9	34.2
R & Mtce	226.9	690.8	152.3
Depreciation	1165.7	671.3	137.4
Total	1565.3	3974.1	757.3
Power (000's KWHrs)	26933.0	14351.4	1667.6
Cost/KWHr	**0.058**	**0.277**	**0.454**

Therefore the additional cost of diesel generation is $0.219 per KWHr.

To establish the relationship between flow and the level of hydro generation, the 1988 flow data for the East Vaisigano was compared to the level of total generation. This gave a generation level of 1,660,000 KWHrs per month for a monthly average flow of 1 m^3/sec. The assumed flow decline over 14 years of 0.165 m^3/sec or a decline of 0.012 m^3/sec/year for the two months of June and July. The loss of generating from the decline is therefore 0.012 times 1,660,000 KWHrs/month times 2 months or 39840 KWHrs per year.

It is assumed that the project might reverse that decline at the same rate from project year 5 to 20, or a $8725 increase per year.

Benefits from Reduced Soil Erosion

The on-site impacts of soil erosion are not known in Western Samoa. Conditions such as the high rate of weathering of parent material lead to a compensating level of soil formation. Furthermore declines in productivity due to soil erosion are partly covered by the fallow period for land under shifting cultivation. Thus this on site impact is likely to be difficult to estimate.

The off-site impacts were considered by the EAPU to include build up of silt in the mouth of the Vaisigano, increased costs for operation and maintenance of power generation and water supply, and effects on reef ecology.

i. The costs of silt build up in the Vaisigano river mouth are the costs of increased flooding due to higher water levels from the build up. Alternatively the costs can be measured in terms of the costs to Public Works of excavation of the accumulated material.

ii. The costs to the water supply system of silty water have been felt particularly by the consumer with extra wear on taps and ballcocks. These effects have resulted in both increased costs and higher water losses. With the proposals under the new Water Supply scheme for filtration these costs will be shifted onto the supply scheme as higher maintenance costs for the filtration plant. These costs are not presently known, but will be the relevant costs when the Pilot Project impacts begin to occur.

iii. The abrasive effects of silty water may result in higher costs of turbine maintenance in the hydro generation plants on the Vaisigano.

iv From discussion with senior Fisheries Division officials, the impacts of silty water on reef ecology are generally agreed to be significant. There is a loss of productivity from the reef. This is caused by reduced sunlight to coral and reef flora, silt blocking the polyp's hole and as a result the coral dies, the filling of holes with the consequent loss of a breeding site, the burying alive of slow moving animals, the loss of algae on coral disrupting the food chain and the reduced production of oxygen from seaweed. To estimate the costs the area of reef subject to deposits from silty water needs to be surveyed. Information is required on productivity of reef areas unaffected by silty water but subject to similar intensity of harvesting. The decline in productivity may have been the subject of research and estimates are needed. The value of the reduced output of reef seafood can be valued in terms of the price where items are available for sale, or in terms of purchased substitutes where appropriate.

In terms of the projects impacts, the source of eroded material causing the problems is important. Nelson (1983) in his Annex on the Vaisigano catchment, found that most sedimentation came from the construction roads, the intake channel spillway and channel below the bell tower in the Alaoa reservoir area. Sediment carried out to the harbour is largely from erosion of stream banks in the Bottomlands area and little is from valley slope erosion. The projects soil conservation works are directed to preventing sedimentation from roads and adjacent slopes. The proposals for dealing with other sources of sedimentation needs clarifying. It is not clear what proportion of the existing soil erosion problem in the catchment is to be reduced as a result of the Pilot Project.

Benefits from Reduced Wet Season Flood Flows

This is the converse benefit of 3, increased dry season flows, where improved hydraulic condition of the catchment can reduce flood peak flows and thus reduce the costs of flooding. Baisyet (1989) records that 1982 floods in Apia resulted in damage estimated to be WS$ 700,000. Similar problems resulted from the flooding in January 1989. These costs are the result of flooding in both the Fuluasou and Vaisigano catchments. The distribution of costs between the two catchments needs investigation, as each catchment could be the basis for further proposals for mitigation works and activities. Historical flood costs need to be adjusted to the current tala values used in the analysis. For adjusting values, a construction index is preferred for most damages; however the CPI can be used if it is the only available index.

Data on flood flows and how the project may effect their levels may be difficult to produce. Staff and budget constraints make this data difficult to obtain. The short period of records will make estimates of flood probability fairly unreliable. To estimate flood reduction benefits the costs of a particular flood need to be related to be flood frequency or the risk of such a flood occurring. The impact of catchment condition (degree of forest cover for example), needs to be related to effect on flood flow levels. Data should be sought on this.

A8.3.3 Summary of the Analysis

The results for costs and benefits able to be valued in this preliminary exercise show that the expected net benefit flow over a period of 20 years reflect the significance significance of the Vaisigano catchment to national hydro power generation and indicate that even small impacts on expected river flows will have large cost or benefit implications. While other impacts and costs may also be potentially significant, the technical link between Pilot Project activities and these impacts needs to be clarified.

Table A8.20 *Agroforestry Net Benefit Stream*

Year	Incremental Net Rev/Acre	Incremental Acreage : Year Plt Acres	2 1	3 2	4 4	5 5.5	Total
1	-185						
2	825		-185				-185
3	186		825	-370			455
4	186		186	1650	-740		1096
5	632		186	372	3300	-1018	2841
6	632		632	372	744	4538	6286
7	632		632	1264	744	1023	3663
8	632		632	1264	2528	1023	5447
9	632		632	1264	2528	3476	7900
10	632		632	1264	2528	3476	7900
11	632		632	1264	2528	3476	7900
12	632		632	1264	2528	3476	7900
13	632		632	1264	2528	3476	7900
14	632		632	1264	2528	3476	7900
15	632		632	1264	2528	3476	7900
16	632		632	1264	2528	3476	7900
17	632		632	1264	2528	3476	7900
18	632		632	1264	2528	3476	7900
19	632		632	1264	2528	3476	7900
20	632		632	1264	2528	3476	7900

APPENDIX 9: INTRODUCTORY NOTES ON GEOGRAPHICAL INFORMATION SYSTEMS (GIS) AND ASSOCIATED CARTOGRAPHY

Cartography is the science of map-making.

GIS is a computer means for making many different map displays from stored geographical information, such as rivers, towns, roads, soils and land use. In that sense, GIS is a modern tool to help the cartographer display and plot out individual maps for users, which would take far more time and skilled draughting to make by hand.

The GIS is a collection of:

HARDWARE
- input device (digitiser or scanner)
- computer (for processing data) with
- data storage (disk or tape) and
- graphics screen (for display) and
- output device (plotter)

SOFTWARE
- specially-written computer programmes to organise the stored data and "drive" it to the display or plotter while the map is being designed and produced.

DATA
- the stored information in the form of roads, rivers, cadastral boundaries, etc., organised in data files with attributes (e.g. class or type of road) and coordinates for positioning it.

MANAGER
- last (but not least) the person in charge of the system, trained in the hardware, software and the logic of cartographic design, data collection, editing and inputting to the system.

Modern GIS's are becoming much more user-friendly, so that users with little computer skills can use the GIS to create their own maps and analyse data with the help of the system manager. This is the sort of system aimed at for Western Samoa (i.e. it can be used by land planners, agriculture and forestry experts, etc.).

When a system is set up decisions are needed on:

(1) the types of information to be included;

(2) the accuracy to which they will be input;

(3) the planned users of the system (access) and restrictions on who may change the data bases, and how;

(4) future growth of the system (i.e. to ensure that a system has capacity to deal with growth);

(5) the database structure and spatial foundation, i.e. land parcels, grid-coordinates and relational positioning inside the system;

(6) the method of data input.

(1) Types of information - The "backbone" of a system will normally be the topography and/or cadastre to which thematic (e.g. soils, land use, etc.) data sets are overlaid. Generally the topo detail is kept to a simpler level than on, say, a topo map because of the problems in handling large, complex databases. Having put the "backbone" data into the system, the themes decided on must be captured and organised into the GIS structure.

(2) Accuracy - It is absolutely vital that the standards of accuracy of data are known and recorded when the data is input. Otherwise, the relationship between, say, a soil boundary and a stream or road (input earlier) will be completely unknown. As this is what a GIS is designed to display, the system will be useless if the relationship of different data sets is not known. A "system standard" of x, y and z accuracy must be decided on before any data is input, and kept to. In the case of unreliable data, it must be labelled in the GIS (in a way that will be displayed every time the data is used) as inferior to the other data. (A strong point of GIS is that such data can be upgraded progressively in the database.).

A chosen data accuracy standard can be simply expressed (for example):

at 1:50 000 scale: x, y, position will be within 2mm (100m on ground)

at 1:50 000 scale : z height will be within 50 metres (say, half a contour interval if the database has 100m contours)

(3) Planned Uses and Access - A GIS is expensive to set up. The main cost is not the computer but the work in planning, organising and inputting the database and training staff to be expert in GIS. Planning will include not just planning the system but also planning on who will use the system and benefit from it. A GIS without clearly-identified user needs would be like a ship without a rudder. There is also high cost in running the system in future years, so it is necessary to show that it will do needed tasks more cheaply than by manual means.

It is important that the system be protected from misuse i.e.

- unauthorised persons changing the database
- unauthorised persons off-loading data

The database must be regarded in the same way as, say, a cadastral plan recording office with proper routines for creating new plans/record sheets and amending existing ones. Improvements (updating) to the database must be regarded in the same way and recorded properly, when done. Also it is important that unauthorised persons are unable to offload data onto tape or disc. The database has very high value and should only be supplied to customers in the form of a map plot off the plotter. As more GIS capability develops in Western Samoa, so will the value of the database increase and other GIS users may want to download it to save the effort of creating their own. At that stage, a system of revenue-earning licencing will need to be considered.

(4) Future Growth of the System - The system being installed under the ADB/ANZDEC contract is designed to have databases on
- soils
- land use
- land tenure
- land capability

These will be overlaid on a "backbone" of topography.

The soil information is being obtained by resurvey of soils based on A.C.S. Wright's 1963 surveys and reclassification into the modern soil taxonomy system.

The land use information is being obtained from Western Samoa Government sources and aerial photography. The land tenure data is from cadastral records in DLS, DAFF and WSTEC.

The land capability information is being obtained from the soil, land use and other (e.g. climatic) data.

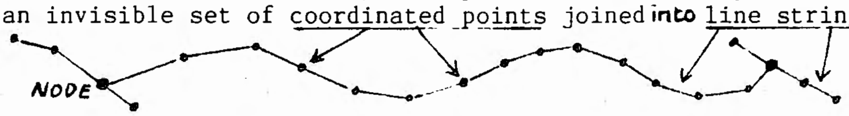
When completed, the system will be able to quickly display and plot out any combination of these factors for any area of Upolu and Savai'i at scales from 1:50 000 down (i.e. 1:75 000, 1:100 000 etc.). It will complement the new 1:50 000 topographical maps now being prepared in DLS.

The future: There is no reason why the system could not be extended in future years to have a parcel-based database capable of displaying cadastral units with their above attributes (soil type, etc.) plus many others such as valuation. This is a popular approach well-developed in Western Australia, for example. For the local installation, the necessary data input standards and compiling will act as a good stimulus within the land-based agencies of government. The GIS will also be an ideal base for adding natural resource (e.g. climatic) data, natural hazard data, etc. The technical specification of the system will allow for later extension and upgrade if new databases and software are desired.

(5) Structure of Database - The computer is a dumb tool which needs very exact instructions (software) to operate. Modern graphics software is designed to perform specific functions according to how complicated the needs are. The normal cartographic preparation of making input data compatible and complimentary before design and draughting applies equally to GIS. In the GIS, instead of preparing a number of overlay drawings (e.g. one for rivers, one for vegetation, etc.) a set of data files must be established. The data is entered as an entity (e.g. roads) with attributes (e.g. sealed road, unsealed road) and the software enables these individual entities and attributes to be "layered" in the database and extracted in any combination.

These files must have a common spatial reference. This is normally the geographical position of data in relation to a grid or projection or both. This ensures, as on a map, that the data sets are orthogonal (correctly scaled and shaped) and correctly related to each other (as on a map). The GIS system has the ability to rescale and refit data sets to each other but this is better done before any data is input to the system.

(6) Data Input - The commonest forms of input are digitising and scanning. In digitising, the compilation drawing is placed on the digitiser and the required lines, points and symbols are traced off with a "mouse" or cursor which acts in the same way as a pen or scriber except that the recording is an invisible set of coordinated points joined into line strings i.e.:-



The spacing or frequency of the recorded points can be varied to give curved lines (such as contours or rivers) a smooth appearance. The closer the points, the greater the amount of data (coordinated points) which need to be stored. If the points are too far apart, line smoothness is lost. GIS's have a menu allowing the operator to go to a line, record its entity (e.g. contour) and its attribute (height above sea level of that particular line) then "draw" along the line with the cursor. Or go to a point symbol (e.g. a soil site, or trig. station) then record the position and the type of symbol from the menu. The line can then be edited by visually displaying the line or symbol or by having a check plot plotted out onto transparent material which can then be placed over the compilation map or drawing for checking. Numbers (e.g. soil codings) and letters (e.g. map names) can be positioned then keyed in using the keyboard (rather like a typewriter, but with extra buttons). The software allows the characters to be put above, below or either side of the true position in a horizontal, vertical or slanted mode. Most thematic (e.g.soil) data is in the form of polygons or irregular boundaries enclosing a soil with a particular set of attributes. The logic for inputting these is is explained during "hands on" instruction. The system being installed in DLS and DAFF will rely on digitising. This is referred to as "vector mode" data capture.

Scanning: Here, the data compilation sheet is put on a rotating drum and "read" by a scan head moving slowly along the drum. The rate can be varied so that the width of each scan line can be as fine as 1/1000 inch or finer. Along the scan path (i.e. around the drum) the line is broken up into small units or "pixels" which are simply recorded as binary bits of "black" or "white" information. No "bit" of data has any linking relationship with any other "bit" so a process known as "vectorising" (i.e. making the data relational, into lines, etc.) must be gone through. The expense of scanning means that it is only useful for capturing very dense compilation (e.g. close contours) and from fairly neat compilation sheets, as subsequent editing and conversion to vector format requires an expensive workstation input. There will be no scanning capability on the DLS/DAFF system.

Conclusion:

Whether for GIS or a CAD (computer-assisted draughting) operation, digital cartography is the way of the future. However those operating such systems must realise that they need the same rigorous draughting/ cartography training which stresses:

good compilation

good graphic design

good integrity (accuracy)

good quality output

good client relations and service

REMEMBER the preparation and inputting of data is just as exacting and rigorous as for conventional cartography and cadastral draughting. There are no short-cuts. GIS has no magical properties to make wrong data right. The saying is "RUBBISH IN, RUBBISH OUT!" However, once good data is in the GIS, it can be used thousands of times with confidence and accuracy.

The main compilational (data capture) scale for the Western Samoa GIS will be 1:20 000 (i.e. the NZMS 174 Topographical series). When the data base is complete (topographical and soils, land use, land capability) the first product will be a set of 18 1:50 000 maps for which a specification is attached.

These notes are preliminary only: technical instruction in the GIS will be given by Dr David Giltrap on his return to Western Samoa in late June 1989.

Duncan McCormack

Duncan D. McCormack
Project Cartographer
Apia, 1st June 1989

APPENDIX 10

ADB/W. SAMOA LAND RESOURCE PLANNING PROJECT · SCHEDULE FOR MONITORING DATA INPUT (GIS/MAP PROGRAMME)

1:20 000 SHEET NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
BASE MAPS (INCLUDING CONTOURS)	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	B C	LINES DIGITISED
																													DETAIL LABELED
																													EDITED : IN D.B.
SOILS																													LINES DIGITISED
																													POLYGONS LABELED
																													EDITED: IN D.B.
LAND USE (TENURE AND USE)	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	T U	LINES DIGITISED
																													POLYGONS LABELED
																													EDITED : IN D.B.

LAND CAPABILITY (COMPILED DIRECT TO 1:50000 SHEETLINES)							DATA COMPILED/DIGITISED
							POLYGONS LABELED
							EDITED : IN DATA BASE
1:50000 SHEET NUMBER	S1	S2	S3	U1	U2	U3	

SOIL LEGENDS ________ [COMPILED] [IN SYSTEM] [EDITED READY FOR MAP OUTPUT] (INCLUDES REFERENCES, CREDITS, etc)

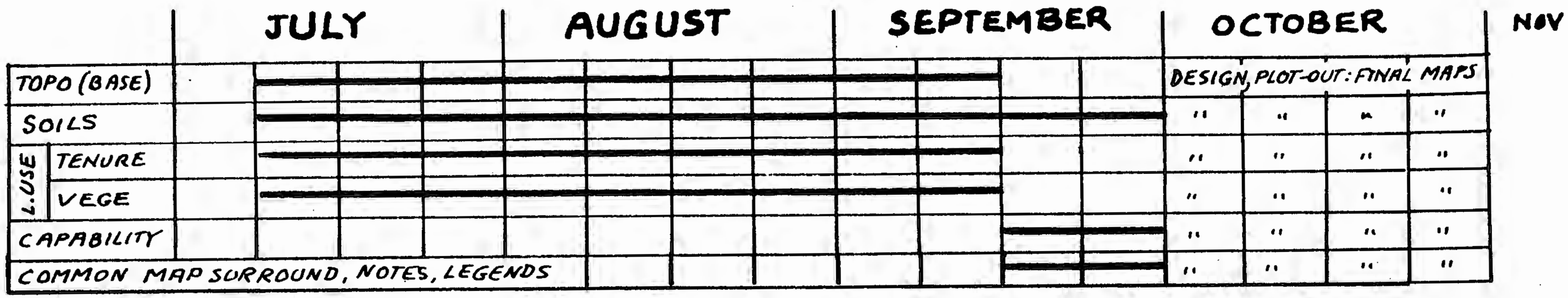
LAND USE LEGEND ________ [COMPILED] [IN SYSTEM] [EDITED READY FOR MAP OUTPUT] (INCLUDES REFERENCES, CREDITS, etc)

LAND CAPABILITY LEGEND ____ [COMPILED] [IN SYSTEM] [EDITED READY FOR MAP OUTPUT] (INCLUDES REFERENCES, CREDITS, etc)

MAP SURROUND AND NOTES, SCALE, ETC. ___ [COMPILED/AGREED] [IN SYSTEM] [EDITED READY FOR MAP OUTPUT]

ADB/W. SAMOA LAND RESOURCE PLANNING PROJECT.

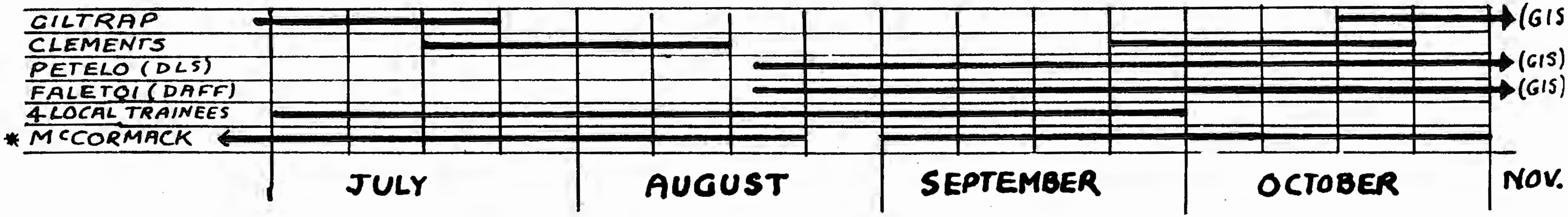
SPATIAL DATA INPUT/EDIT PROGRAMME FOR 1:50000 MAPPING (SOILS, LAND USE, LAND CAPABILITY) AND GEOGRAPHICAL INFORMATION SYSTEM (G.I.S.)



11 WEEKS DATA BASE ENTRY PERIOD. MANNING OF SYSTEM: 2 CONSULTANTS, PLUS 4 TRAINEES IN ROTATION (2 AT ANY TIME). THEREFORE, ON 6 DAY WEEK BASIS = 66 SYSTEM DAYS AVAILABLE. ALLOWING FOR INSTRUCTION ETC, A SYSTEM-DAY IS EQUAL TO 3 MAN-DAYS (198 MAN-DAYS TOTAL) THE DIGITISING TASK HAS BEEN ASSESSED AT:

BASE MAPS	60 MAN-DAYS	190 MAN-DAYS
SOIL MAPS	60 MAN-DAYS	
LAND USE MAPS	40 MAN-DAYS	
LAND CAPABILITY	20 MAN-DAYS	
MAP SURROUND	10 MAN-DAYS	

THEREFORE UNTIL MAP PLOTOUT, THE SYSTEM WILL BE DEDICATED TO MAP PRODUCTION, WITH NORMAL GIS SYSTEM IMPLEMENTATION PHASING IN DURING MID-OCTOBER. NOTE: THE ELAPSED PERIODS (HEAVY LINES) DO NOT INDICATE CONTINUOUS WORK BUT THE PERIOD IN WHICH EACH OPERATION MUST BE COMPLETED. A SHEET-BY-SHEET APPROACH WILL BE ADOPTED. TEAM LEADER* MANAGES SYSTEM, PROVIDING CARTOGRAPHIC COMPILATION/DESIGN/EDITING/TRAINING (NOT INCLUDED IN ABOVE MANNING CHART) ALSO: A PROJECT PROGRESS CHART WILL MONITOR ALL ASPECTS OF THE PROGRAMME. THE CHART BELOW RELATES CONSULTANT/LOCAL PERSONNEL TO THE ABOVE CHART, AND PROGRAMME.



APPENDIX 11: MAP SPECIFICATION (as product from GIS)

Note: - Lineweights and typesizes are not specified: these will be finalised at the various stages when checkplots are made and edited.

- A mock-up* has been made of the final map format plotted on a standard 30"x40" sheet of paper. The colour coding on the mock-up has no reference to the final map appearance: it is solely to show the levels of commonality or uniqueness to the different maps (for GIS). There are 6 map sheetlines, 3 for Savai'i and 3 for Upolu.

For each of these 6, there are 3 thematic maps on the same base; soils, land use and land capability.

This gives a total of 18 maps. On mock-up;

BLACK data is common to all 18 maps.

RED data is common within each set of thematic maps (e.g. common for the 6 soil maps). Therefore there will be three files of this data, one for each thematic class.

GREEN data is data unique to each sheetline and will therefore only be common to the 3 thematic maps falling on that geographic sheetline (1 soil, 1 land use, 1 land capability).

(1) Topographical Base

Roads all motorable roads will be shown, as defined on the NZMS 174 series, as one class. Where amendment detail is readily available from the Australian topographical team in Lands and Survey and from the pedology team on this project it will be incorporated. Check before digitising. Non-motorable tracks will not be shown.

Populated Places

Towns will be shown in a large (approx. 7mm) square and named in capitals.

Villages will be shown in a smaller (approx. 4mm) square and named in caps/lower case.

The selection of villages will be those shown in the bolder (12 pt) type on NZMS 174 (sub-villages, buildings or small collections of dwellings will not be shown).

Topographical Features

Coastal: All points or capes marked in 12 pt type on NZMS 174 will be shown.

Hydrology: All coastline, rivers, streams and lakes shown on NZMS 174 will be shown, with major streams, rivers and hydrographic features such as bays named. Reef delineation will be omitted.

One lineweight for all features

Contours: Imperial contours on NZMS 174 will be used, with equivalent metric heights adjacent (but not breaking the line). The vertical interval will be:

*(can be viewed at project office, Lands and Survey Department)

100ft in coastal flat to sloping areas (plus 50ft coastal contour)
250ft in hill country and steeplands

Craters may be labeled "crater" but not symbolised (show as contours).

Heighted Points: will be shown with name and elevation if readily available.

Descriptive notes, names: a few major items such as Faleolo Airport may be shown.

(NOTE:- All linework derived from the NZMS 174 series at 1:20 000 scale will be suitably generalised to reduce to the prime GIS (and map production) scale of 1:50 000.

- There is no requirement to curve type: straight-line horizontal mode will be used wherever possible, but vertical and slanting capability exists in the GIS.)

(2) Thematic Maps

General comment on thematic specification. The specification is as exacting as possible allowing for the tight time-frame for field assessment of soils, land use and land capability, laboratory analysis of soils, analysis of land use/land capability data and accurate input to GIS data fiels. Normal cartographic practices will be followed, but the maps must be seen as an initial expression of the GIS, easily updatable.

(a) Soil Maps

(i) Soil boundaries: these shall be expressed as polygons in a line more prominent than any of the base map linework (either through boldness, colour printing or a combination of these). The coastal polygons will join to, but not along the coastline.

(ii) Soil descriptions on map face: polygon codings will be in a face and boldness causing them to stand out from base map lettering. Pit and sample sites will be marked by suitable symbols and labels.

(iii) Legends and notes: These will be compiled via GIS software to fit within a rectangle 140mm wide by 950mm deep. This gives ample space to accommodate legend, notes desired and normal bibliographic references.

(b) Land Use Maps

(i) Land use boundaries: These will be compiled from data derived from DAFF and WSTEC records, field surveys and photo interpretation. The tenure/land use categories are:

Production Forest
Protection Forest
WSTEC Estates
Government Land
Freehold Land
Customary Land
Conservation Uses
Livestock only
Coconut & Livestock
Coconut & Cocoa
Coconut & other plantings
Coconut
Cocoa
Banana
Other (lava, domestic use, etc)

The data will be obtained from DLS, DAFF, WSTEC and photointerpretation. Maps will carry a disclaimer regarding legality of boundaries shown. Areas under 20 acres will not be included. Only interfacing boundaries between land classes will be shown. The notes (a) (i), (ii) and (iii) above apply equally to land use maps.

(c) Land Capability Maps

These will be compiled from assessment of the above Soil and Land Use Maps plus other data. The notes (a) (i), (ii) and (iii) above apply.

21/5/89
(D. MacCormack)
PROJECT CARTOGRAPHER